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TIPITAPA-TAMARINDO PROJECT

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PREFEASIBILITY REPORT

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VOLUME II

Supporting Data

Prepared for:

The Government of NICARAGUA

By:

United States Department of the Interior
Bureau of Reclamation

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Volume 2 of 2

Supporting Data
to the
Prefeasibility Report

TIPITAPA-TAMARINDO HYDROELECTRIC PROJECT

NICARAGUA

May 1978

Prepared for:

Republic of Nicaragua - Ministry of Public Works

Prepared by:

United States Department of the Interior - Bureau of Reclamation

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PREFACE

The purpose of this volume is to bind together most of the important information used to prepare the main report. Normally, the basic data and computations or results of studies for a project are presented in various appendixes to accompany the main report. Since the purpose of this report has been served while in draft form (i.e., to help the authorities to make a decision whether to perform feasibility studies of higher accuracy), it was decided to save time and effort by not preparing formal appendixes. However, it was felt necessary to present this volume in order to preserve the opinions and conclusions of the various technicians who studied the project to guide others in future activities related to the Tipitapa-Tamarindo Project.

TIPITAPA-TAMARINDO HYDROELECTRIC AND IRRIGATION PROJECT

Determination of Rainfall Excess

The runoff produced by the design storm for each basin has been estimated using the procedure of the United States Soil Conservation Service which is described in the United States Bureau of Reclamation (USBR) publication "Design of Small Dams." Basically, the method consists of:

a. Classification of the soils of the basin into hydrologic groups A, B, C, or D which depend upon absorption capacity and rainfall retention.

b. Identification of land use with its dominant characteristic for each hydrologic group.

c. The combination of the two above points permits the identification of the hydrologic complex.

d. By a single relationship of a rainfall-runoff curve number (cn) one may obtain the average runoff equation or graph which relates rainfall to runoff.

e. The method considers three conditions of antecedent soil moisture in relation to the curve numbers. For the present study, the most favorable condition, AMC 111, was selected, in which the soil is found to be nearly saturated due to 5 days of rainfall prior to the occurrence of the design storm.

Brito River Basin (See Figure 1). - This basin is located on the Rivas Isthmus with approximately 220 square kilometers of area above the Miramar damsite. Its soils normally are found to be covered by vegetation but having shallow depth, being of moderate to fine structure, and moderate permeability. For the present study, the soils of this basin have been classified in the hydrologic group C. Table 1 gives the runoff results for each 2-hour period from the beginning of the selected design storm shown.

Tamarindo River Basin (See Figure 2). - This basin is situated between Lake Managua and the Pacific Ocean. There is about 244 square kilometers of area above the damsite on the Tamarindo River. Like the previous case, the soil of this basin has been classified as hydrologic group "C," and the same storm has been applied. The results of runoff for each 2 hours are tabulated in table 1.

Lake Managua Basin (See Figure 3). - This basin has an area of approximately 5,830 square kilometers. In order to facilitate the work at this level of study, the hydrologic grouping of the soils were generalized and classified within group "B." This group pertains to soils of moderate to good drainage with moderately fine to moderately sandy texture. They have a medium rate of water transmissibility and regularly present an appreciable vegetal coverage. The values of runoff applicable to the selected storm are shown in table 2.

Lake Nicaragua Basin (See Figure 4). - For this basin, the same values of the storm and precipitation computed in the Prefeasibility Study of the San Juan River were used, taking into account the incremental drainage area from the San Isidro damsite.

Unit Hydrographs

In order to compute the unit hydrographs, the method described in the USBR publication "Design of Small Dams" was used. Initially, dimensionless hydrographs were determined and then the unit hydrographs were derived, taking into consideration the physical and hydrologic characteristics of each particular watershed.

Lag Time. - Lag time is an index of the time of concentration of the runoff from a watershed and is defined as the average time from the center of excess rainfall to the occurrence of one-half the volume of runoff enclosed below the flood hydrograph at the point of interest in the riverbed. For the watersheds of the rivers draining into Lakes Managua and Nicaragua, the lag times have been calculated using the following equation:

$$Lg = 0.611 \left(\frac{l \cdot l_{ca}}{\sqrt{s}} \right)^{0.38}$$

where:

Lg = lag time, in hours
l = length of main drainage watercourse from the point of interest to the watershed divide, in kilometers
l_{ca} = length of the main watercourse from the point of interest to the intersection of the perpendicular from the centroid of the area (ca) to the stream alinement
s = slope of the principal watercourse from the point of interest to the divide, in meters per kilometer

Table 1. - Effective rainfall - Brito and Tamarindo River Basins

Hydrologic Soil Group "C"
Curve No. 86 for Condition III
Initial Abstraction (Ia)
Minimum Retention Soil Type "C" = 3 mm/hr

Time h	ΔP mm	ΣP mm	ΔPe mm	ΣPe mm	ΔLoss mm	2 h R. O. mm
1	7	7	2.37	2.37	4.63	
2	0	7	-0.63	-3.00	3.00	2
3	14	21	0.01	0.64	13.36	
4	6	27	0.22	0.21	5.79	1
5	28	55	7.62	7.40	20.60	
6	10	65	12.08	4.47	5.53	12
7	1	66	10.08	-2.00	3.00	
8	0	66	7.08	-3.00	3.00	0
9	0	66	4.08	-3.00	3.00	
10	0	66	1.08	-3.00	3.00	0
11	1	67	0.92	-2.00	3.00	
12	4	71	0.08	1.00	3.00	1
13	7	78	4.08	4.00	3.00	
14	21	99	22.08	18.00	3.00	22
15	40	139	59.08	37.00	3.00	
16	35	174	88.18	29.10	5.90	66
17	11	185	96.18	8.00	3.00	
18	7	192	100.18	4.00	3.00	12
19	40	232	137.18	37.00	3.00	
20	64	296	195.51	58.33	5.67	95
21	19	315	211.51	16.00	3.00	
22	1	316	209.51	-2.00	3.00	16
23	1	317	207.51	-2.00	3.00	
24	0	317	204.51	-3.00	3.00	0
25	0	317	201.51	-3.00	3.00	
26	2	319	200.51	-1.00	3.00	0
27	6	325	203.51	3.00	3.00	
28	16	341	216.51	13.00	3.00	16
29	30	371	243.51	27.00	3.00	
30	54	425	294.51	51.00	3.00	78
31	39	464	330.51	36.00	3.00	
32	8	472	335.51	5.00	3.00	41
33	49	521	381.51	46.00	3.00	
34	14	535	392.51	11.00	3.00	57
35	17	552	406.51	14.00	3.00	

Table 1. - Effective rainfall - Brito and Tamarindo River Basins
(Continued)

Time h	ΔP mm	ΣP mm	ΣPe mm	ΔPe mm	ΔLoss mm	2 h R. O. mm
36	22	574	425.51	19.00	3.00	33
37	17	591	439.51	14.00	3.00	
38	16	607	452.51	13.00	3.00	27
39	13	620	462.51	10.00	3.00	
40	22	642	481.51	19.00	3.00	29
41	14	656	492.51	11.00	3.00	
42	24	680	513.51	21.00	3.00	32
43	13	693	523.51	10.00	3.00	
44	22	715	542.51	19.00	3.00	29
45	0	715	539.51	-3.00	3.00	
46	1	716	537.61	-2.00	3.00	0
47	3	719	537.51	0.00	3.00	
48	3	722	537.51	0.00	3.00	0
49	1	723	535.51	-2.00	3.00	
50	0	723	532.51	-3.00	3.00	0
51	1	724	530.51	-2.00	3.00	
52	8	732	535.51	5.00	3.00	5
53	1	733	533.51	-2.00	3.00	
54	16	749	546.51	13.00	3.00	13
55	10	759	553.51	7.00	3.00	
56	2	761	552.51	-1.00	3.00	7
57	20	781	569.51	17.00	3.00	
58	38	819	604.51	35.00	3.00	52
59	3	822	604.51	0.00	3.00	
60	19	841	620.51	16.00	3.00	16
61	1	842	618.51	-2.00	3.00	
62	1	843	616.51	-2.00	3.00	0
63	13	856	626.51	10.00	3.00	
64	13	869	636.51	10.00	3.00	20
65	9	878	642.51	6.00	3.00	
66	4	882	643.51	1.00	3.00	7
67	0	882	640.51	-3.00	3.00	
68	0	882	637.51	-3.00	3.00	0
69	4	886	638.51	1.00	3.00	
70	1	887	636.51	-2.00	3.00	1
71	4	891	637.51	1.00	3.00	
72	0	891	634.51	-3.00	3.00	1

Table 2. - Effective rainfall - Lake Managua Basin

Hydrologic Soil Group "B"
Curve No. 86 for Condition III
Initial Abstraction (Ia)
Minimum Retention Soil Type "B" = 5 mm/hr

Time h	P mm	Σ P mm	Σ Pe mm	Δ Pe mm	Δ Loss mm	2 h R. O. mm
1	9	9	1.74	1.74	7.26	
2	4	13	0.74	-1.00	5.00	2
3	0	13	-4.26	-5.00	5.00	
4	0	13	-9.26	-5.00	5.00	0
5	1	14	-13.26	-4.00	5.00	
6	5	19	-13.26	0.00	5.00	0
7	7	26	-11.26	2.00	5.00	
8	2	28	-14.26	-3.00	5.00	2
9	6	34	-13.26	1.00	5.00	
10	16	50	-2.26	11.00	5.00	12
11	2	52	-5.26	-3.00	5.00	
12	8	60	-2.26	3.00	5.00	3
13	11	71	3.74	6.00	5.00	
14	4	75	2.74	-1.00	5.00	6
15	0	75	-2.26	-5.00	5.00	
16	0	75	-7.26	-5.00	5.00	0
17	0	75	-12.26	-5.00	5.00	
18	0	75	-17.26	-5.00	5.00	0
19	0	75	-22.26	-5.00	5.00	
20	2	77	-25.26	-3.00	5.00	0
21	1	78	-29.26	-4.00	5.00	
22	5	83	-29.26	0.00	5.00	0
23	9	92	-25.26	4.00	5.00	
24	12	104	-18.26	7.00	5.00	11
25	20	124	-3.26	15.00	5.00	
26	13	137	4.74	8.00	5.00	23
27	32	169	31.74	27.00	5.00	
28	21	190	47.74	16.00	5.00	43
29	41	231	83.74	36.00	5.00	
30	31	262	109.74	26.00	5.00	62
31	25	287	129.74	20.00	5.00	
32	41	328	165.74	36.00	5.00	56
33	25	353	185.74	20.00	5.00	
34	51	404	231.74	46.00	5.00	66
35	33	437	259.74	28.00	5.00	

Table 2. - Effective rainfall - Lake Managua Basin (Continued)

Time h	P mm	ΣP mm	ΣPe mm	ΔPe mm	ΔLoss mm	2 h R. O. mm
36	18	455	272.74	13.00	5.00	41
37	7	462	274.74	2.00	5.00	
38	2	464	271.74	-3.00	5.00	2
39	2	466	268.74	-3.00	5.00	
40	1	467	264.74	-4.00	5.00	0
41	2	469	261.74	-3.00	5.00	
42	17	486	273.74	12.00	5.00	12
43	14	500	282.74	9.00	5.00	
44	8	508	285.74	3.00	5.00	12
45	5	513	285.74	0.00	5.00	
46	2	515	282.74	-3.00	5.00	0
47	4	519	281.74	-1.00	5.00	
48	9	527	284.74	3.00	5.00	3
49	11	538	290.74	6.00	5.00	
50	2	540	287.74	-3.00	5.00	6
51	17	557	299.74	12.00	5.00	
52	13	570	307.74	8.00	5.00	20
53	7	577	309.74	2.00	5.00	
54	15	592	319.74	10.00	5.00	12
55	26	618	340.74	21.00	5.00	
56	9	627	344.74	4.00	5.00	25
57	10	637	349.74	5.00	5.00	
58	11	648	355.74	6.00	5.00	11
59	2	650	352.74	-3.00	5.00	
60	6	656	353.74	1.00	5.00	1
61	3	659	351.74	-2.00	5.00	
62	5	664	351.74	0.00	5.00	0
63	3	667	349.74	-2.00	5.00	
64	3	670	347.74	-2.00	5.00	0
65	3	673	345.74	-2.00	5.00	
66	10	683	350.74	5.00	5.00	5
67	10	693	355.74	5.00	5.00	
68	3	696	353.74	-2.00	5.00	5
69	1	697	349.74	-4.00	5.00	
70	8	705	352.74	3.00	5.00	3
71	6	711	353.74	1.00	5.00	
72	0	711	348.74	-5.00	5.00	1

For the watersheds of Brito and Tamarindo Rivers, the equation for lag time as a function of their physical characteristics is as follows:

$$Lg = 0.715 \left(\frac{l \cdot l\ ca}{\sqrt{s}} \right)^{0.38}$$

Both of these basins have topographic characteristics different from the mountainous type of the upper zone where the main streams are of relative short length and pronounced slope. The waters of these streams drain into the Pacific Ocean.

Base Flow. - For the watersheds of Brito and Tamarindo Rivers, the hydrograph records were estimated from the respective stations at Miramar and Tamarindo, located short distances from each damsite. For the drainage basins of Lakes Managua and Nicaragua, base flow values determined in the San Juan River Study were used.

Retention Loss. - A retention loss of 3 millimeters per hour was used for the Brito and Tamarindo watersheds. A larger value of 5 millimeters was used for Lake Managua watershed. A loss of 1 millimeter per hour was used for Lake Nicaragua watershed.

Brito River Watershed. - Three flood events which occurred at the Miramar station on May 31, 1933, July 28, 1973, and September 19, 1974, were selected for the derivation of the unit hydrograph for this basin. The dimensionless graph and the unit hydrograph are shown in tables 3 and 4. The physical parameters of the basin are shown at the bottom of the tables.

Tamarindo River Watershed. - A flood event which occurred September 10-15, 1975, at Tamarindo hydrologic station was selected for derivation of the unit hydrograph. The dimensionless graph and the unit graph corresponding to the damsite are shown in tables 5 and 6, respectively.

Lake Managua Watershed. - As indicated on figure 3, this basin was divided into four principal subbasins with the physical parameters shown at the bottom of the figure. For subbasins 1, 2, and 3, the unit hydrographs derived in the San Juan River Study were used. The hydrologic station at El Jicaral on the Sinecapa River was considered representative of these areas. For the present study of subbasin 4, the hydrograph of Ochomogo River at Las Enramadas was revised and adjusted to a flood occurring on June 7, 1975. Also, in the present case, corrections were made to the areas of subbasins 3 and 4. The dimensionless hydrographs for Ochomogo and Sinecapa Rivers are tabulated in tables 7 and 8. The results of the unit hydrographs for the four subbasins of Lake Managua are given in table 9.

Table 3. - Brito River - Miramar dimensionless hydrograph

Time h	Q m^3/s	Vol. m^3/s-h	$\frac{Q(Lg+D/2)}{m^3/s\text{-day}}$	%(Lg+D/2)
0	0			
	22.27	11.14	18.96	41
2	14.14	29.34	12.04	83
	8.50	40.66	7.24	124
4	5.50	47.66	4.68	165
	3.80	52.31	3.24	207
6	2.75	55.59	2.34	248
	2.00	57.96	1.70	290
8	1.60	59.76	1.36	331
	1.28	61.20	1.09	372
10	1.04	62.36	0.89	414
	0.87	63.32	0.74	455
12	0.73	64.12	0.62	496
	0.61	64.79	0.51	538
14	0.51	65.35	0.43	579
	0.42	65.81	0.36	620
16	0.35	66.20	0.30	662
	0.30	66.52	0.25	703
18	0.25	66.80	0.21	744
	0.21	67.03	0.17	786
20	0.17	67.22	0.14	827
	0.14	67.37	0.12	868
22	0.12	67.50	0.10	910
	0.10	67.61	0.08	951
24	0.08	67.70	0.07	993

V = 68.14 m^3/s-h
Lg+D/2 = 2.42 h

V/2 = 34.07 m^3/s-h
K = 0.83259

$$\frac{Lg+D/2}{Vol.} = 0.85159$$

Table 4 - Brito River - Miramar damsite unit hydrograph

Time h	%(Lg+D/2)	Ordinate	$m^3/s/mm$
2	42	19.00	10
4	83	12.00	6
6	125	7.25	4
8	166	4.75	3
10	208	3.25	2
12	249	2.30	1
14	291	1.70	1
16	333	1.32	1
18	374	1.07	1

AREA = 220 km^2

Lg = 3.81 h

L = 24 km

Lca = 8.9 km

S = 6.86 m/km

Table 5. - Tamarindo River dimensionless hydrograph

Time h	Q m^3/s	Vol. m^3/s-h	$\frac{Q(Lg+D/2)}{m^3/s\text{-day}}$	%(Lg+D/2)
0	0			
1	4.00	2.00	0.60	12
2	16.92	12.46	2.55	23
3	44.00	42.92	6.62	35
4	77.60	103.72	11.68	46
5	114.00	199.52	17.15	58
6	134.81	323.93	20.28	69
7	141.00	461.83	21.22	81
8	137.52	601.09	20.69	92
9	129.00	734.35	19.41	104
10	118.14	857.92	17.78	115
11	95.00	964.49	14.23	127
12	75.77	1049.88	11.40	138
13	59.00	1117.26	8.88	150
14	47.43	1170.48	7.14	161
15	35.50	1211.94	5.34	173
16	28.15	1243.77	4.24	182
17	21.50	1268.59	3.24	196
18	17.17	1287.93	2.58	207
19	14.41	1303.72	2.17	219
20	12.09	1316.97	1.82	230
21	10.15	1328.09	1.53	242
22	8.52	1337.42	1.28	253
23	7.15	1345.26	1.08	265
24	6.00	1351.83	0.90	276

V = 1386.08 m^3/s-h

Lg+D/2 = 8.69 h

V/2 = 693.04 m^3/s-h

K = 0.83926

$$\frac{Lg + D/2}{Vol.} = 0.15047$$

Table 6. - Tamarindo River at Tamarindo unit hydrograph

Time h	%(Lg+D/2)	Ordinate	$m^3/s/mm$
2	41	9.25	5
4	82	23.02	13
6	123	15.00	9
8	164	6.40	4
10	205	2.70	2
12	246	1.40	1
14	287	0.99	1
16	369	0.70	4

AREA = 244 km^2

Lg = 3.88 hours

L = 25.7 km

Lca = 12.2 km

S = 13.3 m/km

Table 7. - Ochomogo River at Las Enramadas
dimensionless hydrograph

Time h	Q m^3/s	Vol. m^3/s-h	$\frac{Q(Lg+D/2)}{m^3/s\text{-day}}$	%(Lg+D/2)
0	0			
1	6.00	3.00	0.96	19
2	33.65	22.83	5.37	37
3	90.60	84.95	14.46	56
4	152.63	206.57	24.37	75
5	146.85	356.31	23.45	93
6	115.00	487.23	18.36	112
7	75.00	582.23	11.97	131
8	47.35	643.41	7.56	150
9	36.00	685.08	5.75	168
10	23.35	714.76	3.73	187
11	17.96	735.41	2.87	206
12	13.81	751.30	2.20	224
13	10.62	763.51	1.69	243
14	8.17	772.91	1.30	262
15	6.28	780.13	1.00	280
16	4.83	785.69	0.77	299
17	3.72	789.96	0.59	318
18	2.86	793.25	0.46	336
19	2.20	795.78	0.35	355
20	1.69	797.73	0.27	374
21	1.30	799.22	0.21	393
22	1.00	800.37	0.16	411
23	0.77	801.26	0.12	430
24	0.59	801.94	0.09	449

$V/2 = 402.09\ m^3/s\text{-h}$

$Lg+D/2 = 5.35$ h

$\frac{Lg+D/2}{Vol.} = 0.15966$

$K = 0.76895$

Table 8. - Sinecapa River at El Jicaral
dimensionless hydrograph

Time h	Q m^3/s	Vol. m^3/s-h	$\frac{Q(Lg+D/2)}{m^3/s\text{-day}}$	%(Lg+D/2)
2	4.3	4.3	1.6	27
4	50.7	105.7	19.3	54
6	41.5	188.7	15.8	82
8	31.6	251.9	12.0	109
10	22.9	297.7	8.7	136
12	16.3	330.3	6.2	163
14	11.9	354.1	4.5	190
16	9.4	372.9	3.6	218
18	7.3	387.5	2.8	245
20	5.7	398.9	2.2	272
22	4.9	408.7	1.9	299
24	4.2	417.1	1.6	327
26	3.6	424.3	1.4	354
28	3.1	430.5	1.2	381
30	2.6	436.7	1.0	408
32	2.2	440.1	0.9	435
34	1.9	443.9	0.7	463
36	1.6	447.1	0.6	490
38	1.4	449.9	0.5	517
40	1.2	452.3	0.5	544
42	1.0	454.3	0.4	571
44	0.9	456.1	0.3	599
46	0.7	457.5	0.3	626
48	0.64	458.8	0.24	653
	V	4.1	1.76	
		462.9	89.5	

K_h = 0.855391

V/2 = 231.45 m^3/s-h

Lg+D/2 = 7.35 h

Vol = 19.2875 m^3/s-day

$$\frac{Lg + D/2}{Vol.} = 0.3812235$$

Table 9. - Lake Managua Watershed unit hydrographs

Time h	Subbasin (1) $m^3/s/mm$	Subbasin (2) $m^3/s/mm$	Subbasin (3) $m^3/s/mm$	Subbasin (4) $m^3/s/mm$
2	1	0	5	48
4	16	3	33	63
6	25	22	26	21
8	22	24	18	8
10	18	22	13	4
12	14	20	9	2
14	11	17	7	1
16	9	14	5	
18	7	12	4	
20	6	10	3	
22	5	8	3	
24	4	7	2	
26	3	6	2	
28	3	5	2	
30	3	5	1	
32	2	4	1	
34	2	4	1	
36	2	3	1	
38	2	3	1	
40	1	2	1	
42	1	2		
44	1	2		
46	1	2		
48	1	2		
50	1	2		
52	1	2		
54	1	1		
56	1	1		
58		1		
60		1		
62		1		
64		1		
66		1		
68		1		
70		1		

Lake Nicaragua Watershed. - For this basin, the results found in the San Juan River Study were used. In addition, the hydrographs of the Frio, Medio Queso, and Sabalos Rivers, which drain into the San Juan River above the damsite, are included. The Lake Nicaragua Watershed is shown in figure 4.

Design Floods

Once the unit hydrographs and excess rainfall for each subbasin of the present study were obtained, the design flood for each subbasin was evaluated as described below:

Brito River. - The precipitation excess of table 1 was applied to the unit hydrograph of table 4 in order to obtain the flood hydrograph of table 10. Also shown is the base flow estimated from recorder charts at the Miramar hydrologic station and flood volumes accumulated during the design flood. The flood values (peak equal to 1381 m^3/s) of table 13 are shown graphically in figure 6.

Tamarindo River. - The design flood tabulated in table 11 was obtained by applying the effective rainfall (table 1) to the unit hydrograph (table 5) for the Tamarindo damsite. The base flow was obtained from the hydrograph record at Tamarindo hydrologic station. The flood hydrograph with a maximum peak of 1745 m^3/s is shown graphically on figure 7.

Lake Managua. - It was indicated in previous paragraphs that this watershed was divided into four principal subbasins which can be seen on figure 3. The design flood was determined from the selected storm and the rainfall excess as shown in table 2. The latter was applied to the unit hydrographs of the four subbasins, and these hydrographs were added together to obtain the flood for Lake Managua. This flood is tabulated in table 12 and is shown graphically in figure 8.

Lake Nicaragua. - For this basin, a design flood was obtained by adding the runoff from the incremental drainage area of the Frio, Medio Queso, and Sabalos Rivers above the San Isidro damsite to the design flood as obtained in the San Juan River Study. The values of the hydrographs for Lake Nicaragua Basin are tabulated in table 13. The base flow with the addition of these drainage areas results in a discharge of 104 m^3/s. The last column of the table shows the total value of the hydrograph which is also shown graphically in figure 9.

Table 10. - Design flood - Brito River at Miramar damsite

Time h	Surface runoff m3/s	Base flow m3/s	Total runoff m3/s	Accumulated volume $m^3 \times 10^6$
2	20	10	30	0.14
4	22	10	32	0.37
6	134	11	145	1.00
8	82	12	94	1.9
10	55	12	67	2.4
12	50	12	62	2.9
14	253	13	266	4.1
16	811	13	824	8.0
18	622	13	625	13.3
20	1367	14	1381	20.5
22	1033	15	1048	29.3
24	667	15	682	35.5
26	462	15	477	39.7
28	499	15	514	43.2
30	1103	15	1118	49.1
32	1131	16	1147	57.3
34	1299	16	1315	66.1
36	1213	16	1229	75.3
38	1007	16	1023	83.4
40	931	16	947	90.5
42	950	16	966	97.4
44	937	16	953	104.3
46	652	16	668	110.1
48	428	16	444	114.1
50	297	16	313	116.8
52	229	16	245	118.9
54	277	16	293	120.8
56	253	16	274	122.8
58	690	16	706	126.4
60	578	16	594	131.0
62	356	16	372	134.5
64	452	16	468	137.5
66	357	16	383	140.6
68	231	16	247	142.9
70	186	16	202	144.5
72	152	16	168	145.8
74	112	16	128	146.9
76	50	16	66	147.6
78	32	16	48	148.0
80	30	16	46	148.3
82	9	16	25	148.6
84	2	16	18	148.7
86	1	16	17	148.9
88	0	16	16	149.0

Table 11. - Design flood - Tamarindo River

time h	Surface runoff m³/s	Base flow m³/s	Total runoff m³/s	Accumulated volume m³ x 10⁶
2	10	8	18	0.09
4	31	8	39	0.30
6	91	9	100	0.80
8	173	9	182	1.81
10	116	10	126	2.92
12	57	10	67	3.62
14	150	10	160	4.44
16	639	11	650	7.35
18	1132	11	1143	13.81
20	1320	12	1332	22.7
22	1732	13	1745	33.8
24	1266	13	1279	44.7
26	636	13	649	51.6
28	421	13	434	55.5
30	763	14	777	59.9
32	1479	14	1493	68.1
34	1638	15	1653	79.4
36	1625	15	1640	91.2
38	1413	15	1428	102.0
40	1197	15	1212	112.0
42	1151	15	1166	120.0
44	1125	15	1140	129.0
46	941	15	956	136.0
48	530	15	545	142.0
50	249	15	264	145.0
52	155	15	170	146.0
54	203	15	218	148.0
56	291	15	306	149.0
58	500	15	515	152.0
60	881	15	896	157.0
62	735	15	750	163.0
64	484	15	499	168.0
66	485	15	500	171.0
68	367	15	382	175.0
70	219	15	234	177.0
72	123	15	138	178.0
74	62	15	77	179.0
76	40	15	55	179.0
78	21	15	36	180.0
80	6	15	21	180.0
82	2	15	17	180.0
84	1	15	16	180.2
86				
88				

Table 12. - Lake Managua design flood

h	Sub-asin 1 m^3/s	Sub-basin 2 m^3/s	Sub-basin 3 m^3/s	Sub-basin 4 m^3/s	Precipitation on lake	Base flow	Total runoff	Accumulated volume m^3 x 10^6
2	2	0	10	96	1 667	40	1 815	7
4	32	6	66	126	139	40	409	15
6	50	44	52	42	278	40	506	18
8	46	48	46	112	0	40	292	21
10	80	50	152	710	5 556	40	6 588	46
12	273	90	481	946	694	40	2 524	78
14	420	135	491	747	2 917	40	4 750	105
16	489	204	528	545	139	40	1 945	129
18	474	312	392	202	0	40	1 420	141
20	388	304	275	86	139	40	1 232	150
22	310	270	205	42	278	40	1 145	159
24	258	237	202	543	1 806	40	3 086	174
26	394	353	535	1803	4 583	40	7 708	213
28	849	577	1348	3744	4 444	40	11 002	280
30	1701	1121	2600	6256	10 972	40	22 690	402
32	2936	2114	4058	7725	3 889	40	20 762	558
34	4114	3449	5016	8456	7 639	40	28 714	736
36	5157	4647	5844	8027	4 444	40	28 159	941
38	5681	5813	5530	4870	556	40	22 490	1123
40	5199	6256	4097	1906	278	40	17 776	1268
42	4286	5742	3009	1384	4 028	40	18 489	1399
44	3626	5042	2618	1700	1 667	40	14 693	1518
46	3229	4584	2336	1164	0	40	11 353	1612
48	2778	4143	1806	537	417	40	9 721	1688
50	2338	3570	1501	623	139	40	8 211	1752
52	2060	3134	1453	1473	2 361	40	10 521	1820
54	2093	2856	1830	2022	1 806	40	10 647	1896
56	2200	2893	1906	2448	2 083	40	11 570	1976
58	2396	2957	2236	2545	2 222	40	12 396	2062
60	2497	3184	2066	1457	278	40	9 522	2141
62	2291	3153	1581	588	139	40	7 792	2204
64	1926	2856	1235	253	972	40	7 782	2258
66	1585	2522	946	354	278	40	5 725	2305
68	1378	2209	919	606	139	40	5 291	2344
70	1299	2015	854	577	2 361	40	7 146	2389

Table 12. - Lake Managua design flood (Continued)

h	Sub-basin 1 m^3/s	Sub-basin 2 m^3/s	Sub-basin 3 m^3/s	Sub-basin 4 m^3/s	Precipitation on lake	Base flow	Total runoff	Accumulated volume $m^3 \times 10^6$
72	1181	1898	733	383	1 250	40	5 485	2435
74	1048	1752	551	186	0	40	3 577	2467
76	936	1581	407	75	0	40	3 039	2491
78	834	1429	320	35	0	40	2 658	2512
80	727	1280	252	15	0	40	2 314	2529
82	627	1107	191	5	0	40	1 970	2545
84	547	971	147	1		40	1 706	2558
86	439	830	126	0	0	40	1 435	2569
88	351	781	113	0	0	40	1 285	2579
90	250	729	101	0	0	40	1 120	2588
92	188	642	78	0	0	40	948	2595
94	157	597	60	0	0	40	854	2602
96	140	553	30	0	0	40	763	2608
98	122	468	16	0	0	40	646	2613
100	107	394	14	0	0	40	555	2617
102	106	314	14	0	0	40	474	2621
104	98	237	14	0	0	40	389	2624
106	87	177	9	0	0	40	313	2626
108	64	146	4	0	0	40	254	2628
110	51	132	1	0	0	40	224	2630
112	26	118	0	0	0	40	184	2632
114	15	106	0	0	0	40	161	2633
116	14	106	0	0	0	40	160	2634
118	9	98	0	0	0	40	147	2635
120	4	77	0	0	0	40	121	2636
122	1	64	0	0	0	40	105	2637
124	0	51	0	0	0	40	91	2638
126	0	26	0	0	0	40	66	2638
128	0	15	0	0	0	40	55	2639
130	0	14	0	0	0	40	54	2639
132	0	14	0	0	0	40	54	2639
134	0	14	0	0	0	40	54	2640
136	0	9	0	0	0	40	49	2640
138	0	4	0	0	0	40	44	2640
140	0	1	0	0	0	40	41	2641

Table 13. - Design flood - Lake Nicaragua Basin with tributaries of the San Juan River above San Isidro damsite

time h	Frio River m³/s	Medio Quezo River m³/s	Sabalos River m³/s	Lake Nicaragua Basin m³/s	Precipitation on Lake Nicaragua m³/s	Base flow m³/s	Total runoff m³/s
2					2 260	104	2 364
4					12 430	104	12 534
6					11 300	104	11 404
8		24	12	642	31 640	104	32 422
10		120	192	3 531	67 800	104	71 747
12	6	818	913	15 814	24 860	104	42 515
14	39	893	1502	18 644	1 130	104	22 312
16	62	602	1286	13 955	0	104	16 009
18	120	351	854	9 249	1 130	104	11 808
20	281	211	574	6 422	0	104	7 592
22	434	171	396	4 507	14 690	104	20 302
24	589	152	321	4 164	0	104	5 330
26	748	124	272	3 470	1 130	104	5 848
28	829	84	210	2 885	10 170	104	14 282
30	811	83	189	2 972	13 560	104	17 719
32	760	168	250	4 010	3 390	104	8 682
34	704	175	318	4 309	1 130	104	6 740
36	613	134	275	3 436	0	104	4 562
38	514	102	184	2 652	2 260	104	5 816
40	462	77	132	2 133	4 520	104	7 428
42	421	40	108	1 794	4 520	104	6 987
44	388	18	96	1 556	1 130	104	3 292
46	384	31	91	1 789	9 040	104	11 439
48	359	106	174	3 100	5 650	104	9 493
50	341	148	281	3 833		104	4 707
52	336	104	229	3 171		104	3 944
54	326	63	148	2 305		104	2 946
56	300	39	103	1 573		104	2 119
58	293	31	70	1 435		104	1 933
60	262	27	52	1 204	5 650	104	7 299
62	233	18	44	1 035		104	1 434
64	289	12	35	924		104	1 364
66	270	8	31	827		104	1 240
68	255	8	27	754	3 390	104	4 538
70	245	8	23	671		104	1 051
72	233	8	18	610	9 040	104	10 013
74	217	8	12	544	2 260	104	3 145
76	199	8	8	490		104	80[illegible]
78	189	4	8	428	3 390	104	4 123
80	181	4	10	495	20 340	104	21 134

Table 13. - Design flood - Lake Nicaragua Basin with tributaries of the San Juan River above San Isidro damsite (Continued)

time h	Frio River m^3/s	Medio Quezo River m^3/s	Sabalos River m^3/s	Lake Nicaragua Basin m^3/s	Precipitation on Lake Nicaragua m^3/s	Base flow m^3/s	Total runoff m^3/s
82	171	20	29	726	1 130	104	2 180
84	130	15	39	679		104	967
86	107	9	39	501	3 390	104	4 139
88	113	5	17	403	5 650	104	6 292
90	111	3	9	347	1 130	104	1 704
92	109	11	6	527	6 780	104	7 537
94	108	58	13	1 440	6 780	104	8 503
96	112	128	92	2 597	3 390	104	6 243
98	117	119	209	2 701	1 130	104	4 380
100	116	141	203	3 697	21 470	104	25 731
102	121	441	468	9 204	23 730	104	34 068
104	155	697	995	14 558	15 820	104	32 329
106	192	904	1321	20 602	62 150	104	85 273
108	240	1677	2198	34 732	49 720	104	88 671
110	395	2157	3311	47 326	74 580	104	127 873
112	564	2570	4160	54 190	4 520	104	66 108
114	810	1848	3912	44 669	22 600	104	73 943
116	1187	1473	3005	36 144	9 040	104	50 953
118	1635	1159	2483	30 488	19 210	104	55 079
120	2128	1093	2168	28 125	13 568	104	47 186
122	2506	1028	1996	25 582	6 780	104	37 996
124	2931	773	1707	21 242	0	104	26 757
126	3125	573	1334	16 711	0	104	21 874
128	3148	395	989	13 383	0	104	18 019
130	3055	331	789	11 135	3 390	104	18 804
132	2894	282	628	9 534	1 130	104	14 572
134	2659	263	530	8 325	12 430	104	24 311
136	2394	256	460	7 342	6 780	104	17 336
138	2121	220	422	6 535	0	104	9 402
140	1869	158	410	5 832	0	104	8 373
142	1669	76	337	5 227	0	104	7 413
144	1482	66	290	4 711	0	104	6 653
146	1358	44	252	4 512	0	104	6 270
148	1205	37	182	3 968	0	104	5 496
150	1159	20	133	3 623	0	104	5 039
152	1166	9	66	3 288	0	104	4 633
154	1088	3	62	2 923	0	104	4 180
156	879	3	43	2 691	0	104	3 270
158	848	3	35	2 417	0	104	3 407
160	490	3	20	2 203	0	104	2 820

Table 13. - Design flood - Lake Nicaragua Basin with tributaries of the San Juan River above San Isidro damsite (Continued)

time h	Frio River m³/s	Medio Quezo River m³/s	Sabalos River m³/s	Lake Nicaragua Basin m³/s	Precipitation on Lake Nicaragua m³/s	Base flow m³/s	Total runoff m³/s
162	715	3	7	1 991	0	104	2 820
164	631	3	3	1 775	0	104	2 516
166	612	2	3	1 558	0	104	2 263
168	585	0	3	1 542	0	104	2 234
170	575	0	3	1 349	0	104	2 031
172	559	0	3	1 266	0	104	1 932
174	531	0	3	1 108	0	104	1 746
176	508	0	2	1 027	0	104	1 641
178	496	0	0	904	0	104	1 054
180	442	0	0	869	0	104	1 415
182	398	0	0	772	0	104	1 274
184	334	0	0	709	0	104	1 147
186	332	0	0	623	0	104	1 059
188	313	0	0	593	0	104	1 010
190	304	0	0	551	0	104	959
192	289	0	0	530	0	104	923
194	279	0	0	461	0	104	844
196	279	0	0	407	0	104	786
198	275	0	0	338	0	104	717
200	275	0	0	334	0	104	713
202	273	0	0	315	0	104	692
204	269	0	0	305	0	104	678
206	267	0	0	286	0	104	657
208	266	0	0	274	0	104	644
210	248	0	0	269	0	104	621
212	229	0	0	251	0	104	584
214	217	0	0	232	0	104	553
216	164	0	0	220	0	104	488
218	122	0	0	200	0	104	426
220	58	0	0		0	104	
222	56						
224	38						
	32						
	17						
	7						
	3						
	3						
	3						
	3						
	3						
	3						
	2						
	0						

Area-Capacity Curves

Miramar Reservoir. - This is located within the Brito River Basin. The area and capacity curves for the damsite have been computed from maps of 1:10 000 horizontal scale and are shown on figure 10.

Tamarindo Reservoir. - This reservoir will be formed by damming the Tamarindo River in the vicinity of the village of the same name. The area and capacity curves were determined from planimetering maps of 1:5000 horizontal scale. The curves corresponding to dikes A and B are shown graphically in figure 11. The present study indicates that the dike B alternative would be the better one from the technical-economic viewpoint.

Lake Managua. - These curves were prepared by the National Energy Commission in 1966 and are shown in figure 12. Presently, there is a new hydrogrpahic survey in progress which will allow preparation of more precise area-capacity curves for a feasibility study phase.

Lake Nicragua. - The area-capacity curves are shown on figure 13. They were prepared from data published by the Canal Commission (1933-1940). Adjustments were made later in the San Juan River Study. It should be noted that the capacity curve of figure 13 is referenced to elevation 29 m, and the volumes given are taken above this elevation.

Flood Routing Studies

El Libano Site - Lake Managua Basin. - At first, the routing of the design flood for the Lake Managua Basin was processed by passing over the spillway at the Libano damsite through Tipitapa River. In view of the fact that at the beginning of the analysis a definite elevation for the spillway crest had not been fixed, an assumed elevation of 39.0 m was used to start the routing. This gave results of water levels and outflows as tabulated in table 14. Later, the level at which the spillway would commence to operate was defined to be 39.40 m but starting the routing of the flood at the level of water in the canal coinciding with normal elevation of Lake Managua at 38.50 m. (This supposes that the pumping plant operations were interrupted at this point making the hydraulic gradient equal to zero.) The final results obtained are shown in table 15 with the maximum water level being at 39.65 m with a corresponding discharge of 40 m^3/s. The capacity curve for Lake Managua (figure 12) was used for this analysis.

Table 14. - Flood routing - El Libano Dam - Tipitapa River

SPILLWAY:

Crest length = 150 meters
Crest elevation = 39 meters (initial)
Discharge coefficient = 2.2

Time h	Inflow m^3/s	Water level meters	Outflow m^3/s
2	1 815	39.01	0.50
4	409	39.02	0.62
6	506	39.02	0.70
8	292	39.02	0.76
10	6 588	39.03	1.4
12	2 524	39.04	2.5
14	4 750	39.05	3.5
16	1 945	39.06	4.4
18	1 420	39.06	5.0
20	1 232	39.06	5.4
22	1 145	39.07	5.8
24	3 086	39.07	6.5
26	7 708	39.09	8.4
28	11 002	39.11	12.0
30	22 690	39.15	20.0
32	20 762	39.21	32.0
34	28 714	39.27	47.0
36	28 159	39.34	66.0
38	22 490	39.41	85.0
40	17 776	39.46	102.0
42	18 489	39.50	117.0
44	14 693	39.54	131.0
46	11 353	39.57	143.0
48	9 721	39.60	152.0
50	8 211	39.62	160.0
52	10 521	39.64	169.0
54	10 647	39.66	179.0
56	11 570	39.69	190.0
58	12 396	39.72	201.0
60	9 522	39.74	212.0
62	7 792	39.76	221.0
64	7 282	39.78	228.0
66	5 725	39.80	235.0
68	5 291	39.81	240.0
70	7 146	39.82	246.0

Table 14. - Flood routing - El Libano Dam - Tipitapa River (Continued)

Time h	Inflow m^3/s	Water level meters	Outflow m^3/s
72	5 485	39.84	253.0
74	3 577	39.85	257.0
76	3 039	39.85	261.0
78	2 658	39.86	263.0
80	2 314	39.87	266.0
82	1 970	39.87	268.0
84	1 706	39.87	269.0
86	1 435	39.88	271.0
88	1 285	39.88	272.0
90	1 120	39.88	273.0
92	948	39.88	274.0
94	854	39.88	275.0
96	763	39.89	275.0
98	646	39.89	276.0
100	555	39.89	276.0
102	474	39.89	276.0
104	389	39.89	276.0
106	313	39.89	276.0
108	254	39.89	276.0
110	224	39.89	276.0
112	184	39.89	276.0
114	161	39.89	276.0
116	160	39.89	276.0
118	147	39.89	276.0
120	121	39.89	276.0
122	105	39.89	276.0
124	91	39.89	275.0
126	66	39.89	275.0
128	55	39.89	275.0
130	54	39.88	275.0
132	54	39.88	274.0
134	54	39.88	274.0
136	49	39.88	274.0
138	44	39.88	274.0
140	41	39.88	274.0
142	40	39.88	273.0
144	40	39.88	273.0
146	40	39.88	273.0
148	40	39.88	272.0
150	40	39.88	272.0

Table 15. - Flood routing - Lake Managua
El Libano Dam - Tipitapa River

Spillway crest elevation = 39.4 m
Crest length = 150 m
Discharge coefficient = 2.2
Beginning with water surface elevation at 38.5 m

Time h	Inflow m^3/s	Elevation meters	Outflow m^3/s
2	1 815	38.5	0
4	409	0.51	0
6	506	0.51	0
8	292	0.51	0
10	2 524	0.54	0
12	6 588	0.52	0
14	4 750	0.55	0
16	1 945	0.56	0
18	1 420	0.57	0
20	1 232	0.57	0
22	1 145	0.57	0
24	3 086	0.58	0
26	7 708	0.60	0
28	11 002	0.63	0
30	22 690	0.68	0
32	20 762	0.75	0
34	28 714	0.83	0
36	28 159	0.92	0
38	22 490	39.00	0
40	17 776	0.06	0
42	18 489	0.12	0
44	14 693	0.17	0
46	11 353	0.21	0
48	9 721	0.25	0
50	8 211	0.27	0
52	10 521	0.30	0
54	10 647	0.33	0
56	11 570	39.37	0
58	12 396	0.40	0.09
60	9 522	0.44	2.40
62	7 792	0.46	5.30
64	7 282	39.49	8.38
68	5 291	0.52	14.14
70	7 146	0.54	17.48

Table 15. - Flood routing - Lake Managua
El Libano Dam - Tipitapa River (Continued)

Time h	Inflow m^3/s	Elevation meters	Outflow m^3/s
72	5 485	0.56	21.10
74	3 577	0.57	23.83
76	3 039	0.58	25.88
78	2 658	0.59	27.69
80	2 314	0.60	29.29
82	1 970	0.61	30.69
84	1 706	0.61	31.91
86	1 435	0.62	32.95
88	1 285	0.62	33.86
90	1 120	0.62	34.67
92	948	0.63	35.37
94	854	0.63	35.98
96	763	0.63	36.52
98	646	0.63	37.00
100	555	0.63	37.40
102	474	0.64	37.74
104	389	0.64	38.02
106	313	0.64	38.24
108	254	0.64	38.42
110	224	0.64	38.56
112	184	0.64	38.68
114	161	0.64	38.78
116	160	0.64	38.87
118	147	39.64	38.95
120	121	39.64	39.02
122	105	0.64	39.07
124	91	0.64	39.11
126	66	0.64	39.14
128	55	0.64	39.16
130	54	0.64	39.17
132	54	0.64	39.18
134	54	0.64	39.19
136	49	0.64	39.20
138	44	0.64	39.20
140	41	0.64	39.21

Tamarindo Damsite. - In this analysis, it was assumed that the level of Tamarindo Reservoir would be at the maximum elevation of Lake Managua of 39.70 m when the design flood for the Tamarindo River Basin would begin (most unfavorable condition). This flood would be passed through a "fuse plug" type of dike, 140 m long. The base (crest) of the spillway would be set at 39 m and the "fuse plug" would fail at elevation 40.50 m. The results of the flood routing are tabulated in table 16 in which it can be seen that the dike would fail at 22 hours after the beginning of the flood. The maximum water level occurs at hour 46 with an elevation of 41.50 m and a corresponding discharge of 942 m^3/s. Obviously, part of the flood waters, according to the hydraulic gradient, will take the route toward Lake Managua, but its effect will be very small in relation to the considerable volumes within both reservoirs which can be appreciated by the area-capacity curves. The capacity curve for Tamarindo Reservoir, figure 11, was used for this study.

San Isidro Damsite. - The normal maximum water level of Lake Nicaragua, which corresponds to the elevation of the spillway crest at San Isidro damsite, has been maintained at its highest possible elevation according to various intentions:

a. Maximize the hydrostatic head of the Miramar hydroelectric plant on the Brito River and at the same time minimize the costs of excavation of the intake canal.

b. Minimize the hydrostatic head for pumping at El Libano Pumping Plant on the Tipitapa River and also minimize the costs of excavation of the intake canal along the Tipitapa River.

c. Obtain greater storage in relation to elevation.

On the other hand, if the useful higher elevation of the reservoir is advantageous for the points cited, a super elevation can also be disadvantageous that during flood periods there is a danger of inundating the shorelines during these critical periods. For this reason, a level has been selected carefully so that the danger of inundation is reduced to a minimum and at the same time it will be a sufficient elevation to obtain a better benefit-cost ratio for the project. Thus it is that the normal maximum water level has been fixed after accomplishing various courses due to the effect of the design flood at different elevations of the spillway crest. The most advantageous result was obtained by setting the spillway crest at elevation 33.00 m. The routing of the design flood (table 13) is shown in table 17 which shows that the extraordinary maximum water level reaches elevation 33.60 m and its corresponding discharge will be about 400 m^3/s over a spillway crest length of 400 m.

Table 16. - Flood routing - Tamarindo Reservoir

Fuse plug dike elevation: 40.50 m
Spillway (broad crest, C = 1.7), elevation = 39 m
Length = 140 m
Begin with water surface at elevation 39.7 m

Time h	Inflow m^3/s	Elevation meters	Outflow m^3/s
2	18	39.70	
4	39	0.71	
6	100	0.72	
8	182	0.74	
10	126	0.77	
12	67	0.79	
14	160	0.81	
16	650	0.88	
18	1143	40.04	
20	1332	0.25	
22	1745	40.52	445
24	1279	0.70	527
26	649	0.77	561
28	434	0.77	560
30	777	0.78	563
32	1493	0.87	610
34	1653	41.03	690
36	1640	0.19	771
38	1428	0.31	838
40	1212	0.39	881
42	1166	0.44	909
44	1140	0.48	931
46	956	0.50	942
48	545	0.47	924
50	264	0.39	877
52	170	0.28	818
54	218	0.18	764
56	306	0.09	721
58	515	0.04	695
60	896	0.04	696
62	750	0.07	706
64	499	0.05	700

Table 16. - Flood routing - Tamarindo Reservoir (Continued)

Time h	Inflow m^3/s	Elevation meters	Outflow m^3/s
66	500	0.02	683
68	382	40.98	662
70	234	40.92	633
72	138	0.84	596
74	77	0.76	557
76	55	0.68	518
78	36	0.60	482
80	21	0.52	447
82	17	0.45	416
84	16	0.38	386
86	16	0.32	360
88	16	0.26	336
90	16	0.20	314

Table 17. - Design flood - flood routing - San Isidro damsite

Crest elevation = 33.0 m L = 400 C = 2.2

Time h	m^3/s	Acc. vol. MMC	From Lake Managua	Total inflow m^3/s	W.S. elev. m	Outflow m^3/s
2	2 364	9	0.6	2 365	33.01	1
4	12 534	62	0.6	12 535	33.01	1
6	11 404	148	0.7	11 405	33.02	2
8	32 422	306	0.8	32 423	33.03	4
10	71 747	681	1.4	71 748	33.05	9
12	42 515	1092	2.5	42 518	33.07	17
14	22 312	1326	3.5	22 316	33.08	22
16	16 009	1464	4.4	16 013	33.09	25
18	11 808	1564	5.0	11 813	33.10	27
20	7 592	1634	5.4	7 597	33.10	29
22	20 302	1734	5.8	20 308	33.11	31
24	5 330	1826	6.5	5 337	33.11	34
26	5 848	1867	8.4	5 856	33.12	35
28	14 282	1939	12.0	14 294	33.12	36
30	17 719	2054	20.0	17 739	33.13	39
32	8 682	2149	32.0	8 714	33.13	42
34	6 740	2205	47.0	6 787	33.13	43
36	4 562	2246	66.0	4 628	33.14	45
38	5 816	2283	85.0	5 901	33.14	46
40	7 428	2331	102.0	7 530	33.14	47
42	6 987	2383	117.0	7 104	33.14	48
44	3 292	2420	131.0	3 423	33.15	49
46	11 439	2473	143.0	11 582	33.15	51
48	9 493	2548	152.0	9 645	33.15	53
50	4 707	2599	160.0	4 867	33.16	55
52	3 944	2630	169.0	4 113	33.16	56
54	2 946	2655	179.0	3 125	33.16	56
56	2 119	2673	190.0	2 309	33.16	57
58	1 933	2688	201.0	2 134	33.16	57
60	7 299	2721	212.0	7 511	33.16	58
62	1 434	2753	221.0	1 655	33.17	59
64	1 364	2763	228.0	1 592	33.17	60
66	1 240	2772	285.0	1 475	33.17	60
68	4 538	2793	240.0	4 778	33.17	61
70	1 051	2813	246.0	1 297	33.17	61
72	10 013	2853	253.0	10 266	33.17	63
74	3 145	2900	257.0	3 402	33.17	64
76	809	2914	261.0	1 070	33.18	65
78	4 123	2932	263.0	4 386	33.18	65
80	21 134	3023	266.0	21 400	33.18	68
82	2 180	3107	268.0	2 448	33.19	71

Table 17. - Design flood - flood routing -
San Isidro damsite (Continued)

Time h	m^3/s	Acc. vol. MMC	From Lake Managua	Total inflow m^3/s	W.S. elev. m	Outflow m^3/s
84	967	3118	269.0	1 236	33.19	71
86	4 139	3137	271.0		33.19	72
88	6 292	3174	272.0	6 564	33.19	73
90	1 704	3203	273.0	1 977	33.19	74
92	7 537	3236	274.0	7 811	33.19	75
94	8 503	3294	275.0	8 778	33.20	70
96	6 423	3348	275.0	6 698	33.20	80
98	4 380	3387	276.0	4 656	33.21	82
100	25 731	3495	276.0	26 007	33.21	86
102	34 068	3710	276.0	34 344	33.22	93
104	32 329	3949	276.0	32 605	33.24	102
106	85 273	4373	276.0	85 549	33.26	117
108	88 671	4999	276.0	88 947	33.30	142
110	127 873	5364	276.0	128 149	33.34	174
112	66 108	5648	276.0	66 384	33.38	205
114	73 943	6152	276.0	74 219	33.41	228
116	50 953	6602	276.0	51 229	33.43	249
118	55 079	6984	276.0	55 355	33.45	268
120	47 186	7352	276.0	47 462	33.47	286
122	37 996	7658	276.0	38 272	33.49	301
124	26 757	7892	275.0	27 032	33.50	313
126	21 847	8067	275.0	22 122	33.51	322
128	18 019	8210	275.0	18 294	33.52	330
130	18 804	8343	275.0	19 079	33.53	337
132	14 572	8463	274.0	14 846	33.53	343
134	24 311	8603	274.0	24 585	33.54	350
136	17 336	8753	274.0	17 610	33.55	359
138	9 402	8849	274.0	9 676	33.56	364
140	8 373	8913	274.0	8 647	33.56	368
142	7 413	8970	273.0	7 686	33.56	371
144	6 653	9020	273.0	6 926	33.56	374
146	6 270	9067	273.0	6 543	33.57	376
148	5 496	9109	272.0	5 768	33.57	378
150	5 039	9147	272.0	5 311	33.57	380
152	4 633	9182	272.0	4 905	33.57	382
154	4 180	9214	272.0	4 452	33.58	384
156	3 720	9242	272.0	3 992	33.58	385
158	3 407	9268	272.0	3 679	33.58	387
160	2 820	9290	271.0	3 091	33.58	388

Table 17. - Design flood - flood routing -
San Isidro damsite (Continued)

Time h	m^3/s	Acc. vol. MMC	From Lake Managua	Total inflow m^3/s	W.S. elev. m	Outflow m^3/s
162	2 820	9311	271.0	3 091	33.58	389
164	2 516	9330	271.0	2 787	33.58	390
166	2 263	9347	270.0	2 533	33.58	391
168	2 234	9363	270.0	2 504	33.58	392
170	2 031	9379	270.0	2 301	33.58	393
172	1 932	9393	270.0	2 202	33.58	393
174	1 746	9406	269.0	2 015	33.59	394
176	1 641	9418	269.0	1 910	33.59	395
178	1 504	9430	269.0	1 773	33.59	395
180	1 415	9440	268.0	1 683	33.59	396
182	1 274	9450	268.0	1 542	33.59	396
184	1 147	9459	268.0	1 415	33.59	397
186	1 059	9466	267.0	1 326	33.59	397
188	1 010	9474	267.0	1 277	33.59	397
190	959	9481	267.0	1 226	33.59	398
192	923	9488	266.0	1 189	33.59	398
194	844	9494	266.0	1 110	33.59	398
196	786	9500	265.0	1 051	33.59	399
198	717	9505	265.0	982	33.59	399
200	713	9511	264.0	977	33.59	400
202	692	9516	264.0	956	33.59	400
204	678	9521	263.0	914	33.59	400
206	657	9525	263.0	920	33.59	400
208	644	9530	262.0	906	33.59	400
210	621	9535	262.0	883	33.59	401
212	584	9539	261.0	845	33.59	401
214	553	9543	260.0	813	33.59	401
216	488	9547	259.0	747	33.59	401
218	426	9550	258.0	684	33.59	401
220	400		250.0	650	33.59	401
220	380		240.0			
222	360		220.0			
224	340		200.0			

In the same table, one can see that the inflows included, which originate in Lake Managua and are given in table 14 (Initial Flood Routing) are much greater than those of table 15 (Final Flood Routing) and therefore are conservative. The capacity curve for Lake Nicaragua, figure 13, was used for this analysis. On the other hand, using the recorded data of Lake Nicaragua water levels*, shows that the maximum level reached was 33.84 m in 1861 and the maximum recorded during the study period of the San Juan River Canal Mission was 33.37 in November 1933.

Miramar Damsite. - This site is located on the Brito River near the Hacienda Miramar. The flood routing study was started with the elevation of the Miramar Reservoir water surface coinciding with the normal maximum water level of Lake Nicaragua of 33.00 m. The flood of table 10 after entering Miramar Reservoir is discharged through a free flow spillway crest at elevation 33.00 m and a length of 33 m. The results are tabulated on table 18.

It can be seen from this table that the maximum water level was 34.9 m with a discharge of 890 m^3/s.

The capacity curve for Miramar Reservoir, figure 10, was used in this analysis.

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* Published data in Appendix I - Hydrology, page 5, from the Report of the Canal Mission, U.S. Engineer Office, Rock Island, Illinois, United States, September 14, 1940.

Estimation of Monthly Runoff

San Isidro Damsite. - The estimation of the monthly surface runoff at the San Isidro damsite, located on the San Juan River downstream from the mouth of the Sabalos River, is based on the discharge of Lake Nicaragua at San Carlos station and added to the incremental proportion of drainage areas between San Isidro and the Pilares hydrologic station adjusted for the responsible and most reliable runoff data. The average monthly runoff at San Isidro was calculated by the following relationship:

$$Q_{si} = Q_{sc} + \frac{A_{si}}{A_p} \times Q_p$$

where:

Q_{si} = monthly runoff at San Isidro site, m^3/s

Q_{sc} = monthly runoff at San Carlos, m^3/s

Q_p = monthly runoff at Pilares, m^3/s

A_{si} = drainage area of the San Juan River at San Isidro, km^2

A_p = drainage area of the San Juan River at Pilares, km^2

Table 18. - Flood routing - Brito River - Miramar Dam

Spilllway crest elevation: 33.00 m
Crest length: 200 m
Spillway coefficient: 1.7 (broad crested weir)
The routing was begun with reservoir surface at elevation 33.0 m

Time h	Inflow m^3/s	Elevation meters	Outflow m^3/s
2	30	33.01	0.6
4	32	0.02	1.1
6	145	0.05	3.4
8	94	0.08	7.3
10	67	0.10	10.3
12	62	0.11	12.3
14	266	0.15	20.0
16	824	0.29	54.0
18	635	0.47	110.0
20	1381	0.71	202.0
22	1048	0.97	323.0
24	682	34.10	395.0
26	477	0.15	420.0
28	514	0.17	430.0
30	1118	0.27	485.0
32	1147	0.43	580.0
34	1315	0.59	680.0
36	1229	0.73	775.0
38	1023	0.82	832.0
40	947	0.85	858.0
42	966	0.88	874.0
44	953	0.90	889.0
46	668	34.88	875.0
48	444	0.80	822.0
50	313	0.69	750.0
52	245	0.58	675.0
54	293	0.48	612.0
56	274	0.40	563.0
58	706	0.38	552.0
60	594	0.41	566.0

Table 18. - Flood routing - Brito River - Miramar Dam (Continued)

Time h	Inflow m^3/s	Elevation meters	Outflow m^3/s
62	372	0.38	554.0
64	468	0.35	534.0
66	383	0.32	518.0
68	247	0.27	489.0
70	202	0.21	551.0
72	168	0.14	414.0
74	128	0.07	378.0
76	66	34.00	341.0
78	48	33.93	305.0
80	46	0.86	273.0
82	25	0.80	245.0
84	18	0.75	219.0
86	17	0.69	176.0
88	16	0.65	177.0
90	16	0.60	160.0
92	16	0.57	143.0
94	15	0.53	132.0
96	15	0.50	121.0
98	15	0.47	111.0
100	15	0.45	102.0

Because of extension and the quality of the basic data pertaining to levels, runoff, etc., the period of this study was adopted for the years 1930-1950 after an analysis of the existing information showed that it would be the most adequate to the study requirements.

Among the corrections made to basic data, there should be mentioned the corrections of levels at San Carlos as well as at Pilares, the updating of the discharge curve for San Carlos, and the unification of different existing discharge curves for Pilares. The correction of the level series for San Carlos was made based on those at Panaloya station and these were affected principally by the dry season levels. The Pilares levels were determined based on the precipitation in the area and the San Carlos levels.

The establishment of a discharge curve at San Carlos station, valid for the period in question, was compiled based on a curve established for the study completed in 1898-1900. It was redone by means of an analysis of the runoff at sections downstream from San Carlos, i.e., Sabalos and Pilares. The average monthly runoff was obtained by means of the use of this curve giving values compatible to the figures derived from observations made on dates after the period of study. For Pilares station, the efforts were concentrated in resolving all the different discharge curves to a single curve to satisfy the whole period of observation (1930-1940) in order to establish a long period of record near Pilares. Then the discharge of the section was extrapolated to the period 1940-1950 using the series of levels for this period.

From the runoff for the reach between San Carlos and Pilares stations, the difference in observed discharges at each was used to calculate the increment of runoff corresponding to the reach San Carlos to San Isidro, assuming that it was proportional to the incremental area. Tables 19 and 20 show the runoff from the lake and that obtained up to San Isidro damsite.

Brito and Tamarindo River Basins. - In table 21 are tabulated the average monthly discharges for Miramar and Tamarindo stations, respectively. The corresponding average annual discharges are 3.15 and 2.30 m^3/s, respectively.

Lake Managua Basin. - This generally is a closed basin during the dry and intermediate periods. It discharges into Lake Nicaragua at irregular intervals during periods of heavy precipitation by way of the Tipitapa River. For this study, Lake Managua was considered as a reservoir which received water from Lake Nicaragua by means of pumping at an average rate of 500 m^3/s and then spills into the Pacific Ocean by way of the Tamarindo River after generating hydroelectric power.

Table 19 - San Carlos Station monthly discharge m^3/s

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average annual
1930	570	480	404	352	320	337	357	393	398	427	395	358	399
1931	328	297	264	238	228	259	333	396	471	576	586	544	377
1932	482	424	367	329	325	365	384	449	508	597	556	508	441
1933	491	434	380	333	316	355	369	442	702	975	1055	1046	574
1934	981	827	706	594	526	550	563	578	606	704	675	599	659
1935	536	464	405	349	336	361	402	491	541	786	842	775	524
1936	669	600	497	439	415	442	472	488	352	667	679	633	529
1937	576	515	447	385	371	399	427	455	527	647	660	614	502
1938	591	528	463	404	371	409	439	506	654	779	897	831	573
1939	766	648	559	464	410	379	367	377	453	490	485	478	490
1940	445	389	341	298	262	300	326	330	313	354	391	411	347
1941	338	304	273	251	234	282	316	346	393	443	437	441	338
1942	407	359	320	306	268	324	365	419	476	560	574	532	409
1943	504	460	414	362	343	375	438	494	508	575	615	584	473
1944	532	465	409	358	348	350	390	405	466	493	470	435	427
1945	417	378	341	305	296	328	352	459	486	557	571	526	418
1946	475	430	385	334	320	356	396	405	405	429	447	449	403
1947	432	389	310	278	311	313	305	293	319	351	402	398	342
1948	363	322	295	326	314	294	305	335	365	422	444	440	352
1949	410	370	329	305	322	298	309	335	383	477	502	490	377
1950	469	433	389	337	306	333	393	452	492	570	656	716	462
	513	453	395	350	331	353	381	421	468	566	588	562	448

Table 20 - San Isidro Site - San Juan River - monthly discharge m^3/s 1930-1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average annual
1930	590	481	405	353	326	378	488	530	429	461	423	436	442
1931	374	307	274	238	242	322	384	482	530	626	610	629	410
1932	503	436	377	339	350	375	463	512	542	629	591	575	474
1933	592	479	414	359	321	377	403	491	730	1011	1148	1185	626
1934	1053	899	769	656	570	666	628	661	655	772	702	655	724
1935	575	499	433	375	342	424	543	593	622	835	958	861	588
1936	745	655	557	487	437	502	522	562	508	700	805	676	596
1937	598	525	456	394	371	419	532	544	597	702	709	696	545
1938	644	552	481	418	404	487	488	522	682	817	976	934	617
1939	830	668	592	475	416	405	416	447	555	566	578	527	540
1940	470	408	356	310	270	315	341	356	335	394	429	438	369
1941	371	327	288	256	235	344	435	438	494	495	492	500	390
1942	442	387	340	307	271	379	453	445	564	613	599	568	447
1943	579	600	426	362	359	573	693	571	579	609	650	654	555
1944	578	503	438	381	351	436	448	501	569	554	569	503	486
1945	477	413	362	324	355	403	397	499	523	609	621	556	462
1946	514	467	408	344	333	445	494	481	475	487	517	508	456
1947	472	439	353	299	315	365	413	368	379	395	471	454	394
1948	394	353	322	348	332	348	404	414	429	469	518	521	404
1949	468	415	349	313	333	345	384	429	459	514	557	562	427
1950	544	456	404	349	371	419	462	502	620	644	739	765	523

Table 21. - Average monthly discharge - Brito and Tamarindo Rivers, m^3/s

River	Station	Date since
Brito	Miramar	1968
Tamarindo	Tamarindo	1954

Month	Brito	Tamarindo
January	1.37	0.38
February	0.99	0.29
March	0.74	0.22
April	0.57	0.17
May	0.75	0.56
June	1.56	3.20
July	1.17	1.08
August	1.32	1.17
September	8.36	5.55
October	14.60	11.90
November	4.28	2.50
December	2.08	0.62
Year	3.15	2.30

Source: Hydrology Annual

Water Balance of the Lakes

In order to show a better view of the hydrologic behavior of the great lakes, it is convenient to include in this report the water balance of Lakes Managua and Nicaragua contained in the Study of the Master Plan for Developing Hydraulic Resources of Nicaragua *. The results published in the cited report are the following:

a. Lake Managua. - Biennial 1969/70-1970/71 (in m^3x 10^6.

Inflow:	
Viejo River	1 311
Sinecapa River	671
Other rivers	1 208
Subtotal runoff	3 190
Rainfall	2 969
Total	6 159
Outflow:	
Evaporation	4 125
Difference	2 034
Addition to storage	2 030

b. Lake Nicaragua. - Inflow to Lake Nicaragua and the San Juan River watershed at El Castillo station, for an average year for the period 1969/70-1971/72 in m^3 x 10^6.

---

* Studies presented to the Central Bank of Nicaragua by Tahal Consulting Engineers, Ltd., December 1974.

Ground water	450
Surface runoff	14 000
Rainfall less evaporation	4 700
Total	19 150

Outflow for an average year for the same period was:

Average runoff - El Castillo	17 600
Average annual amount from storage	900
Total	18 500

The disagreement of this balance is attributed to the lack of accuracy of the data used.

Supply Levels and Reservoir Operation

Since Lake Nicaragua is the source of supply for the Brito alternative as well as for Tamarindo, an analysis was made concerning the availability of water for hydroelectric generation at a rate of withdrawal according to the supply and storage capacity available.

Initially, a mass curve of estimated monthly flows at the San Isidro site on the San Juan River during the period 1930 to 1950 (table 20) was compiled. These flows are to be stored in Lake Nicaragua for later use in one or the other alternatives noted above.

An average annual flow of 500 m^3/s was obtained for the indicated period at which two dry periods (1930-1932 and 1947-1949) and one wet period (1934-1938) were observed.

The mass curve also indicates that between 1933 and 1934 (an interval from dry to wet) there was a large change in storage of approximately 13 250 $m^3 \times 10^6$. During the rest of the period it was observed that changes in storage were less pronounced. Therefore, in order to set the levels of operation, the above-mentioned volume of storage in Lake Nicaragua was used as a base. The normal maximum level was previously fixed at elevation 33.00 m from which the minimum level necessary in order to obtain the noted volume of storage corresponds to elevation 31.50 m (see area-capacity curve for Lake Nicaragua, figure 13).

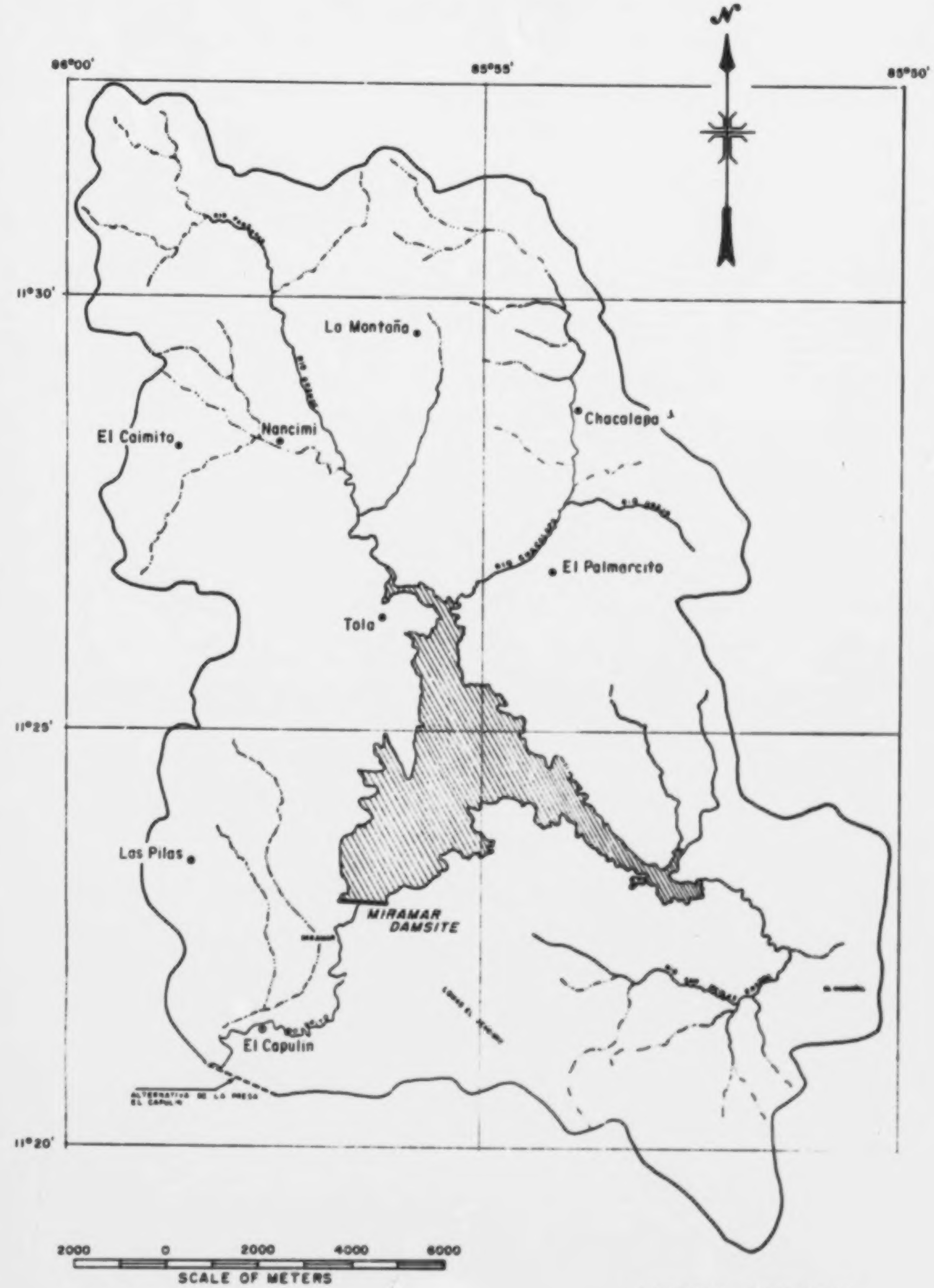
For convenience, in order to obtain a greater normal water elevation, the average level has been set at elevation 32.50. Between this elevation and the normal maximum of 33.00 m there is the necessary storage to avoid spills, to pass over the San Isidro spillway during wet periods, to vary the turbine flows (Brito alternative) or pumping (Tamarindo alternative) from 500 to 625 m^3/s following an operation program according to the water level between these elevations. It was observed that for such a selection of the average water level there was no spill and therefore the elevation was definitely established at 32.50 m.

In the same manner another method of reservoir operation was made at a rate of 490 m^3/s, assuming 10 m^3/s for losses of escape, seepage, evaporation, transpiration, etc. The results of this operation are tabulated in table 22 in which is also shown for each year the energy generated in gigawatt-hours and the average power capacity for the year in megawatts provided in the Brito alternative. At the same time one can see that there were spills during the period 1935 to 1940. The average energy for this alternative during 1930-1950 was 113 gigawatt-hours with an average capacity of 130 megawatts maintaining the levels of operation between 31.50 (minimum) and 33.0 (normal maximum).

Table 22. - Reservoir operation - Lakes Nicaragua and Miramar

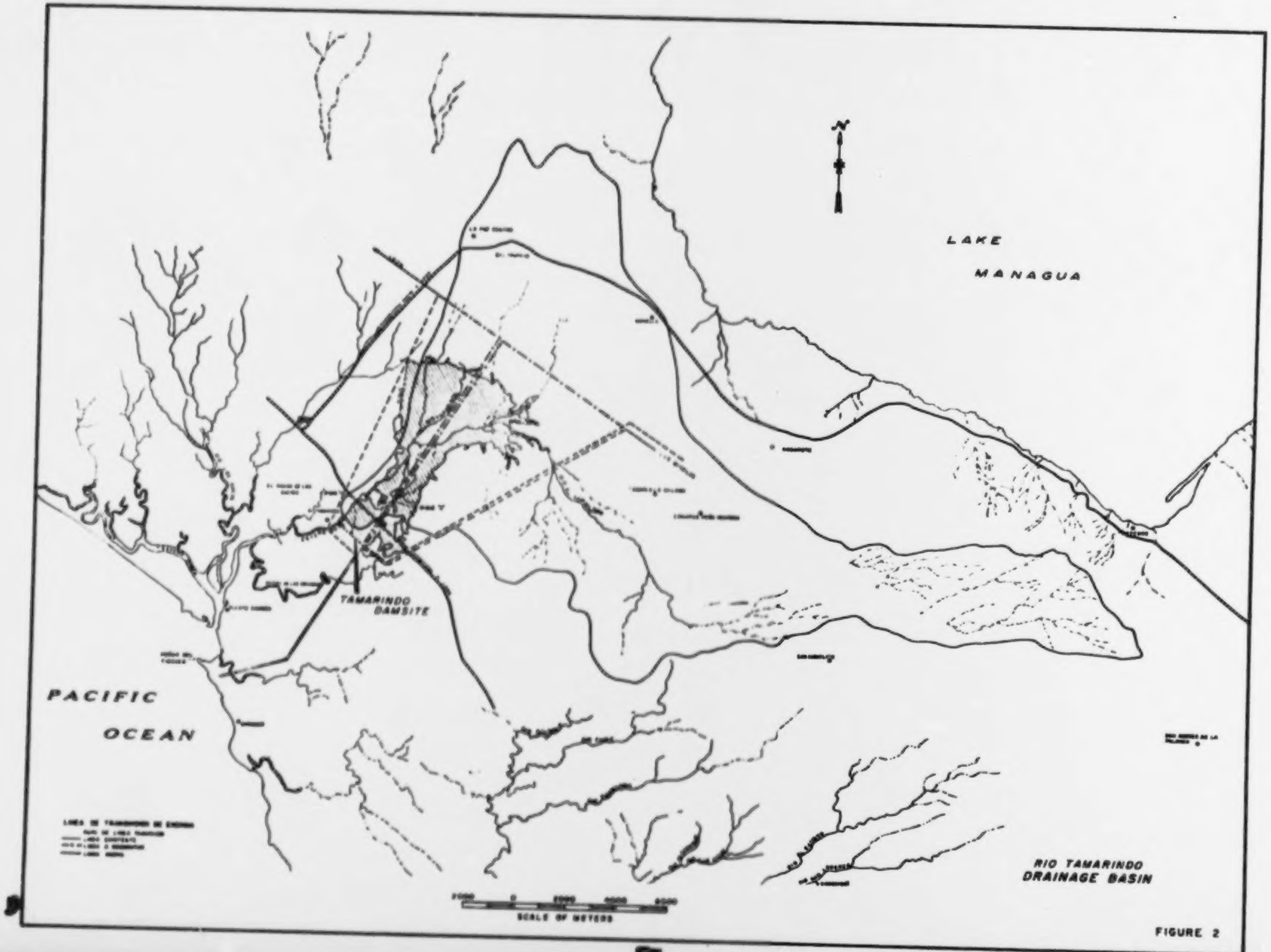
Year	Energy 1/ GW-h	Average capacity 1/ MW	Spill 2/ m^3/s
1930	1135	130	-
1931	1123	128	-
1932	1119	128	-
1933	1122	128	-
1934	1158	132	-
1935	1169	133	28
1936	1177	134	113
1937	1175	134	65
1938	1176	134	90
1939	1177	134	111
1940	1163	133	6
1941	1147	131	-
1942	1137	130	-
1943	1141	130	-
1944	1145	131	-
1945	1141	130	-
1946	1139	130	-
1947	1131	129	-
1948	1087*	124	-
1949	958*	109	-
1950	1075*	123	-
Average	1133	129	

1/ At Miramar Hydroelectric Plant.
2/ Spill at San Isidro spillway, San Juan River.
* Years in which the average turbine flows in some months were below 490 m^3/s.


N
86°00'
85°55'
85°50'
11°30'
11°25'
11°20'
La Montaña
Chacalapa
El Caimito
Nancimi
El Palmarcito
Tola
Las Pilas
MIRAMAR
DAMSITE
El Capulin
ALTERNATIVA DE LA PRESA
EL CAPULIN
2000
0
2000
4000
6000
SCALE OF METERS

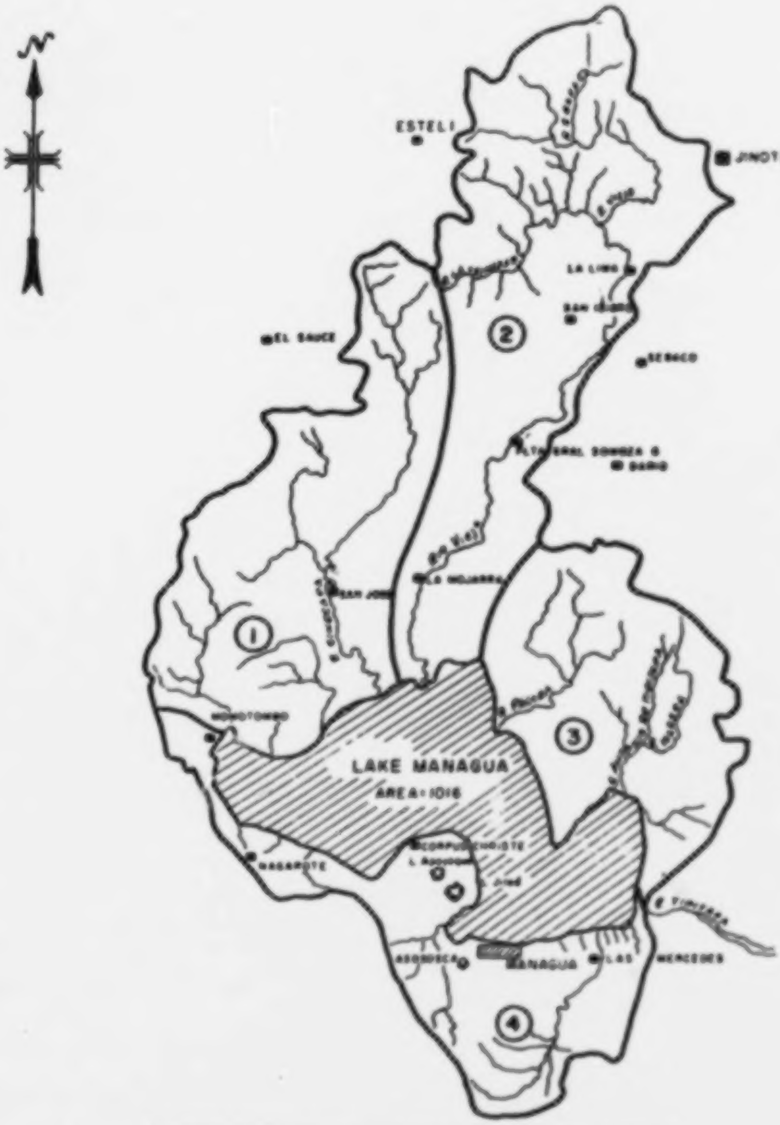
MANAGUA, NICARAGUA
RIO BRITO
DRAINAGE BASIN

FIGURE 1


LAKE MANAGUA
PACIFIC OCEAN
TAMARINDO DAMSITE
N
2000 0 2000 4000 6000
SCALE OF METERS

RIO TAMARINDO
DRAINAGE BASIN

FIGURE 2


N
ESTELI
JINOTEGA
LA LIMA
SAN ISIDRO
EL SAUCE
SEBACO
GENERAL SOMOZA O
DARIO
SAN JOSE
LA MOJARRA
①
②
③
④
MOMOTOMBO
LAKE MANAGUA
AREA=1016
NAGAROTE
CORPUS CHRISTE
L. ASOSOSCA
L. JILOA
ASOSOSCA
MANAGUA
LAS
MERCEDES
R. TIPITAPA

No. BASIN	L (Km)	Lca (Km)	S $\frac{m}{m}$	Lg (Hrs)	AREA (Km²)
1	62.0	36	.0053	8.0	1100
2	120.0	71.0	.0085	12.7	1580
3	42.3	21.2	.0065	5.6	1040
4	26.6	11.3	.0306	2.0	1000

PRINCIPAL DRAINAGE BASIN
OF LAKE MANAGUA

FIGURE 3

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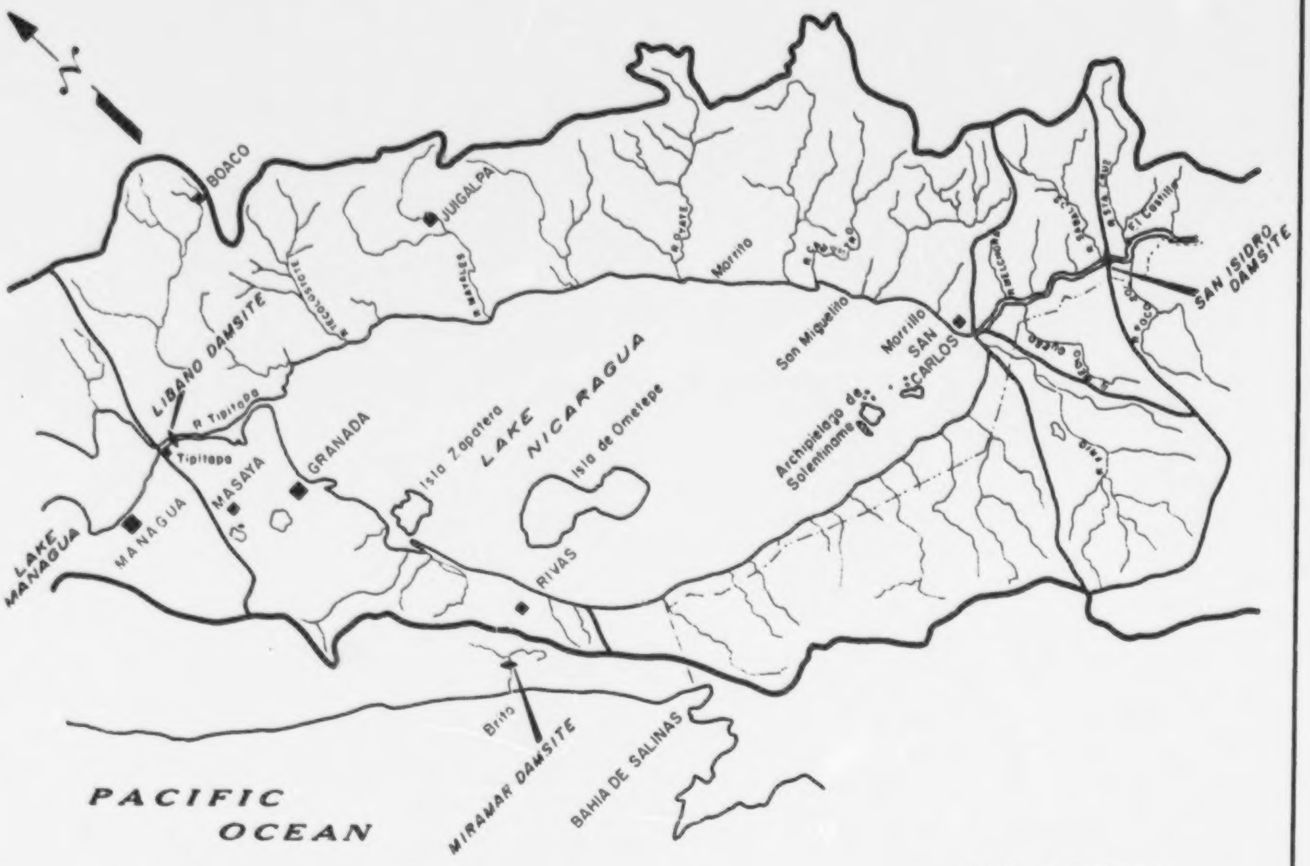
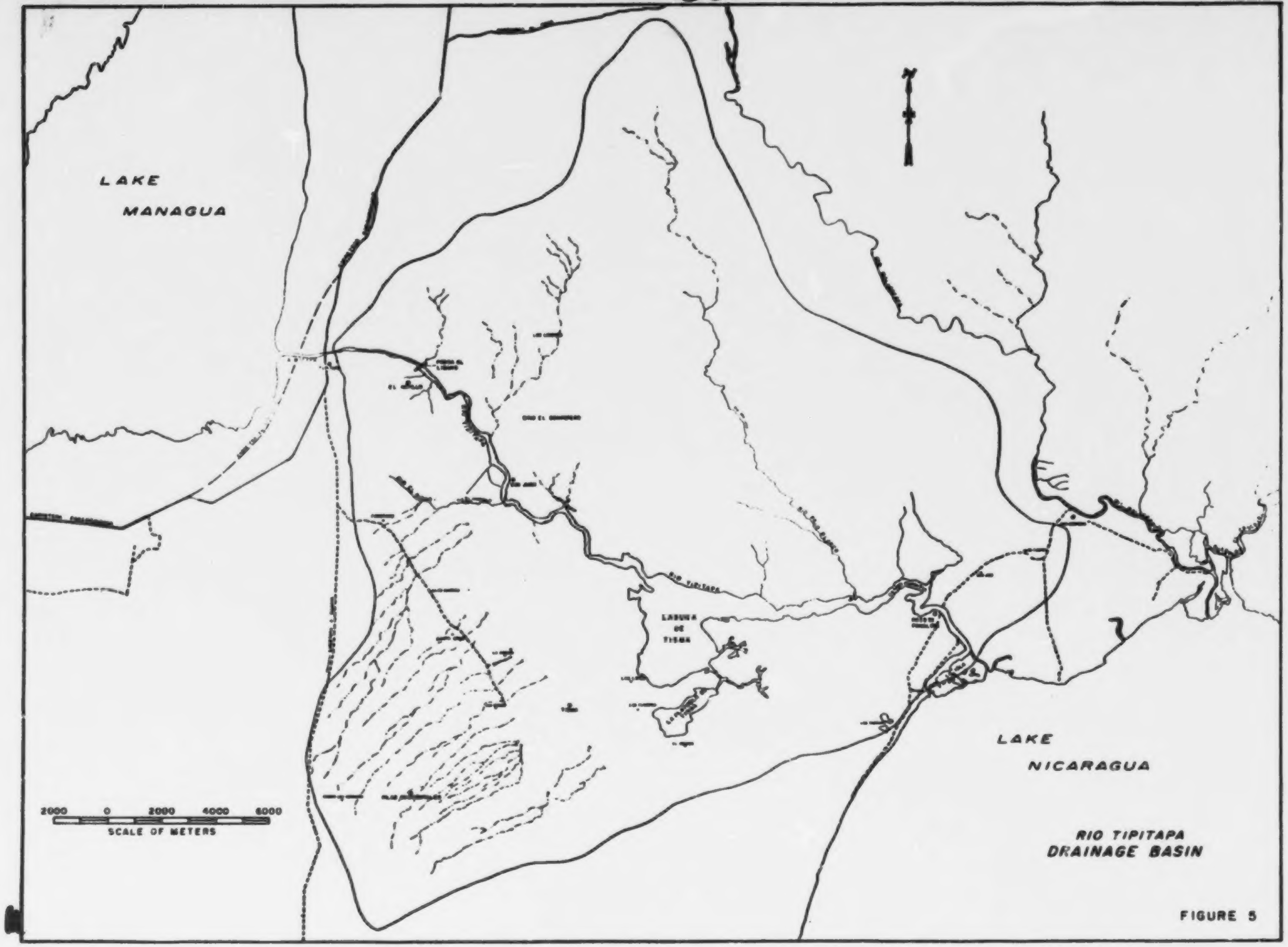

N
BOACO
JUIGALPA
LIBANO DAMSITE
R. Tipitapa
Tipitapa
LAKE MANAGUA
MANAGUA
MASAYA
GRANADA
Isla Zapatera
LAKE NICARAGUA
Isla de Ometepe
RIVAS
Morrito
San Miguelito
Morrillo
SAN CARLOS
Archipielago de Solentiname
El Castillo
SAN ISIDRO DAMSITE
Brito
MIRAMAR DAMSITE
BAHIA DE SALINAS
PACIFIC OCEAN

LAKE NICARAGUA
DRAINAGE BASIN

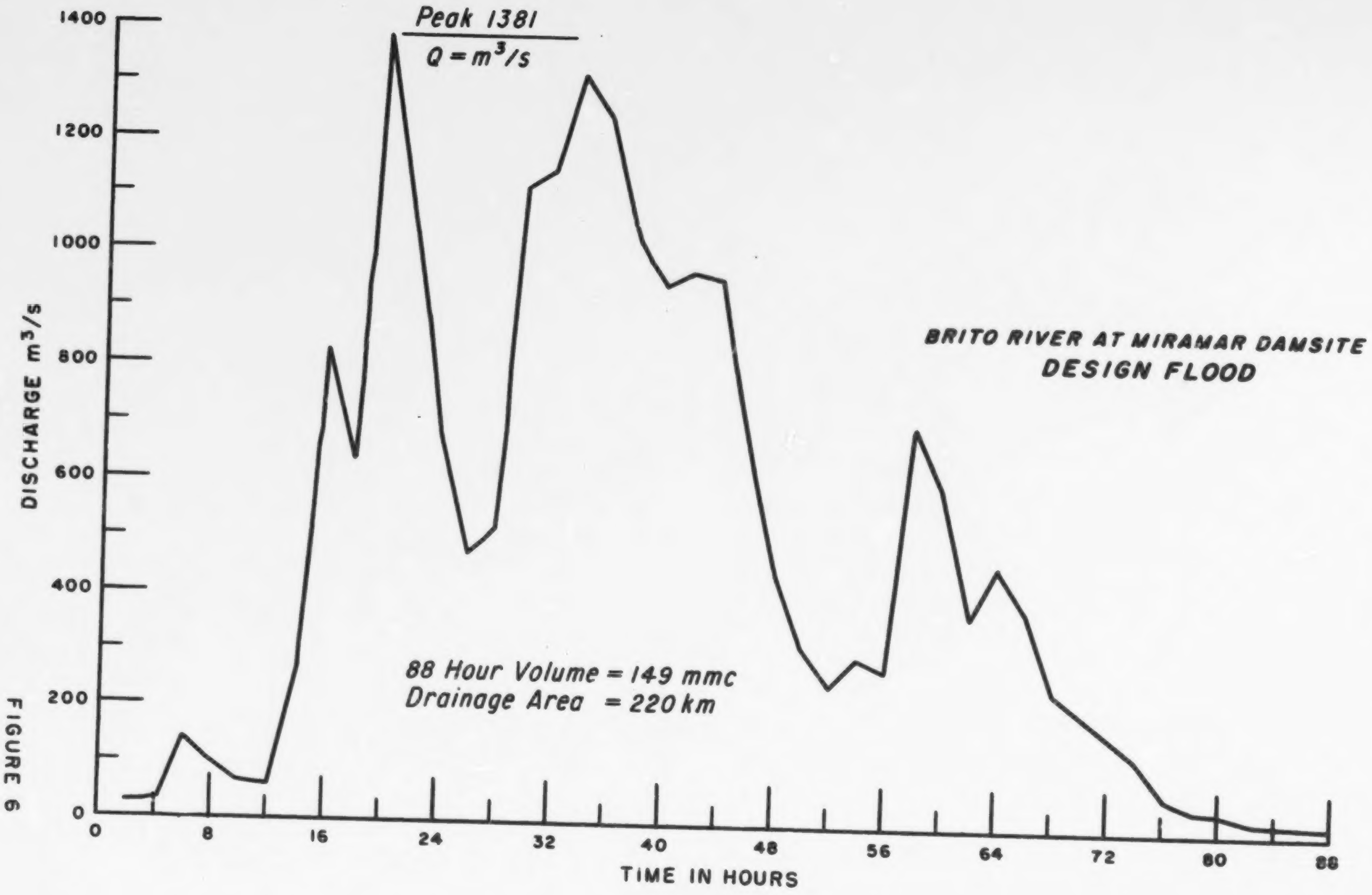
FIGURE 4


LAKE
MANAGUA
LAKE
NICARAGUA
RIO TIPITAPA
LAGUNA
DE
TISMA
2000 0 2000 4000 6000
SCALE OF METERS

RIO TIPITAPA
DRAINAGE BASIN

FIGURE 5

FIGURE 6


Peak 1381
Q = m³/s
BRITO RIVER AT MIRAMAR DAMSITE
DESIGN FLOOD
88 Hour Volume = 149 mmc
Drainage Area = 220 km
DISCHARGE m³/s
1400
1200
1000
800
600
400
200
0
TIME IN HOURS
0
8
16
24
32
40
48
56
64
72
80
88

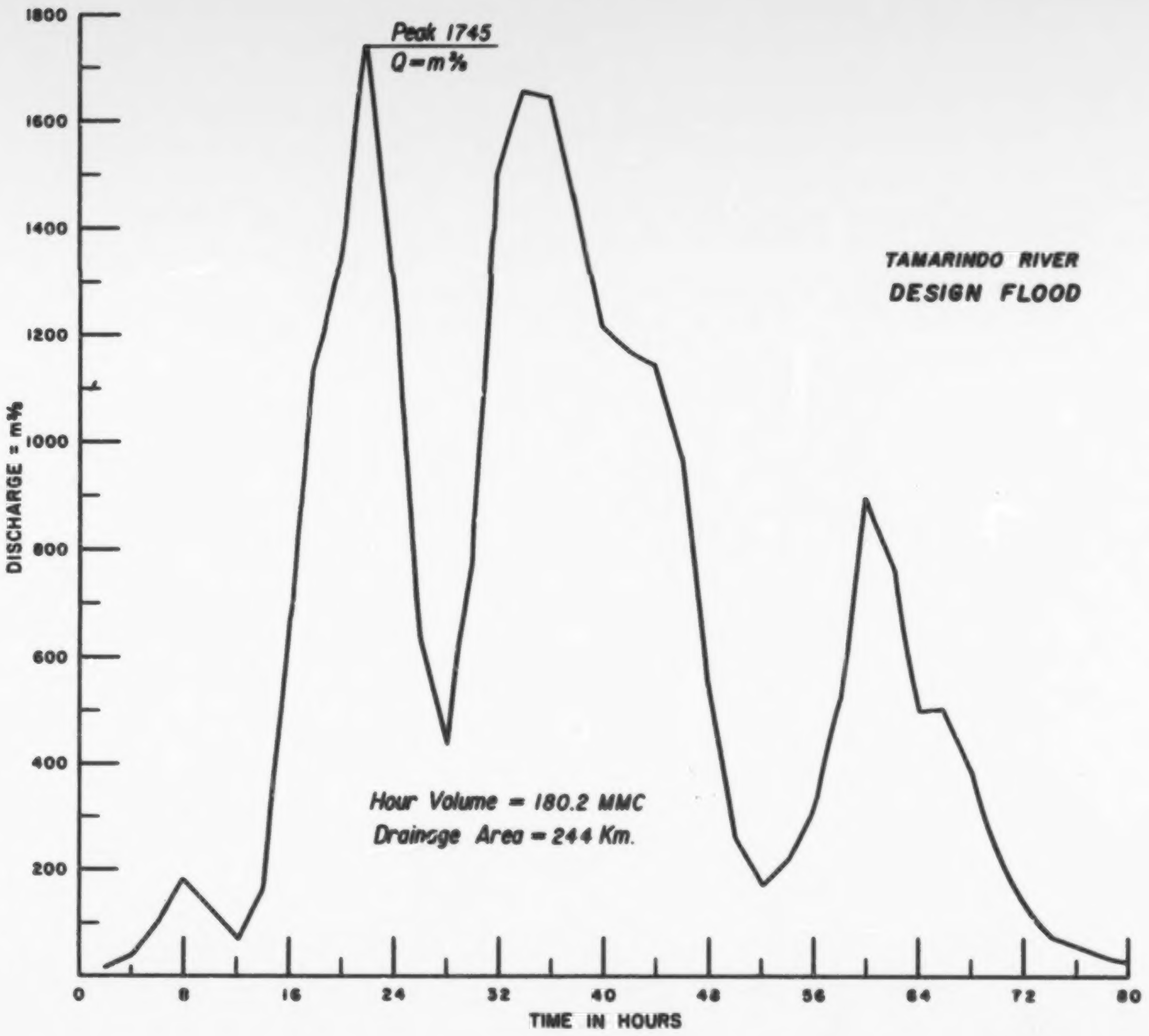

TAMARINDO RIVER
DESIGN FLOOD
Peak 1745
Q=m³/s
Hour Volume = 180.2 MMC
Drainage Area = 244 Km.
DISCHARGE = m³/s
1800
1600
1400
1200
1000
800
600
400
200
TIME IN HOURS
0
8
16
24
32
40
48
56
64
72
80

FIGURE 7

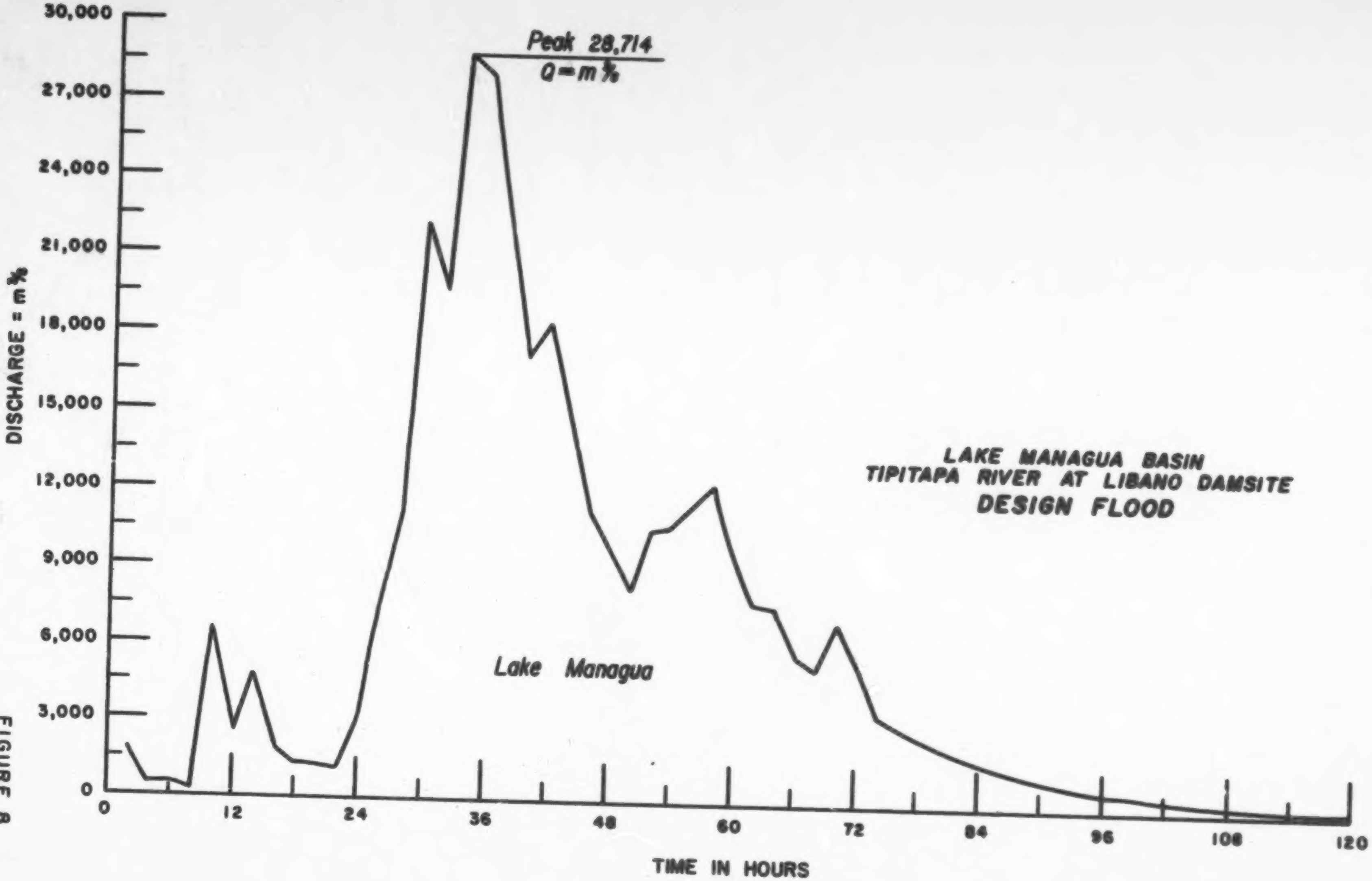
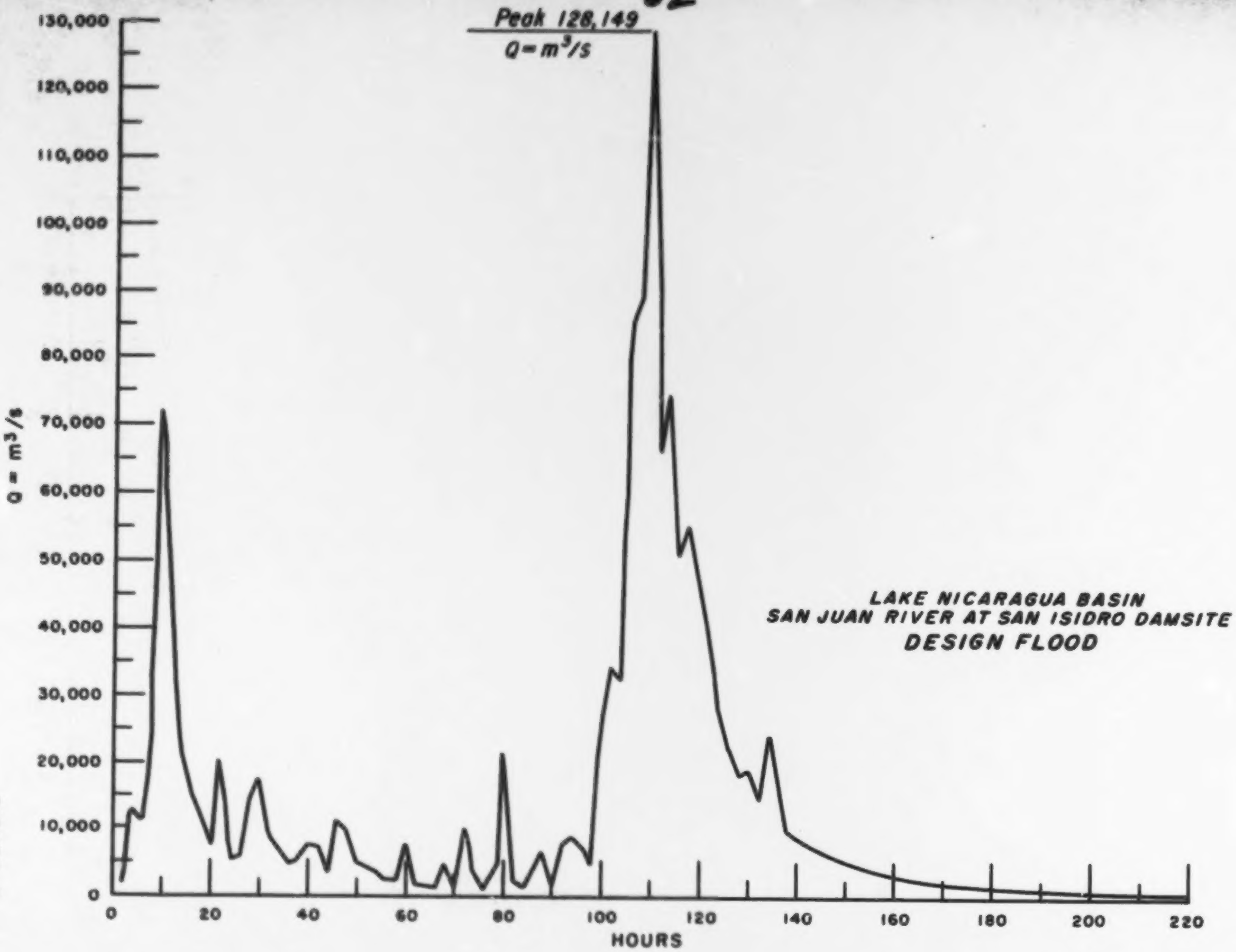

Peak 28,714
Q = m^3/s
LAKE MANAGUA BASIN
TIPITAPA RIVER AT LIBANO DAMSITE
DESIGN FLOOD
Lake Managua
DISCHARGE = m^3/s
30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
0
12
24
36
48
60
72
84
96
108
120
TIME IN HOURS

FIGURE 8



LAKE NICARAGUA BASIN
SAN JUAN RIVER AT SAN ISIDRO DAMSITE
DESIGN FLOOD

FIGURE 9

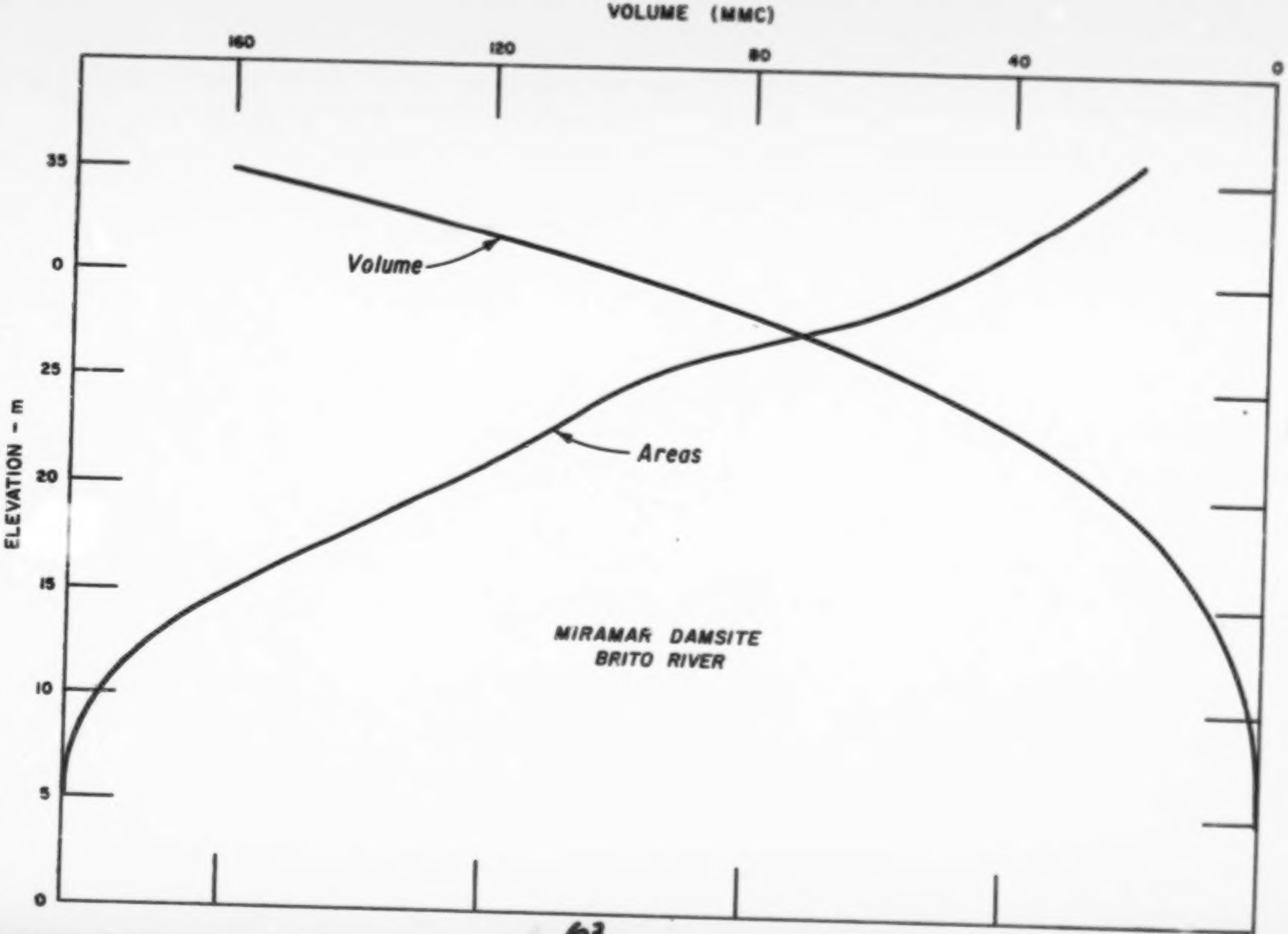
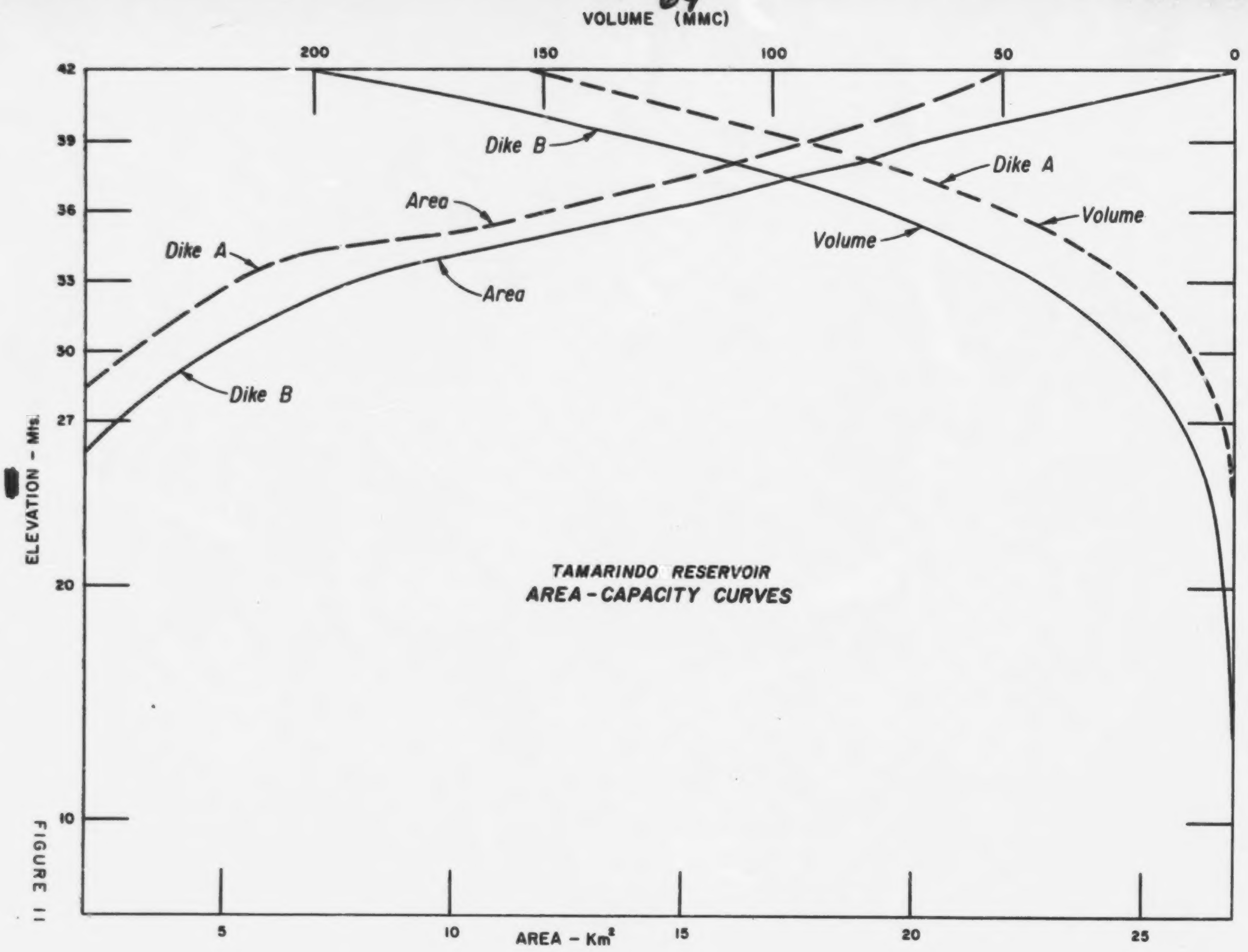
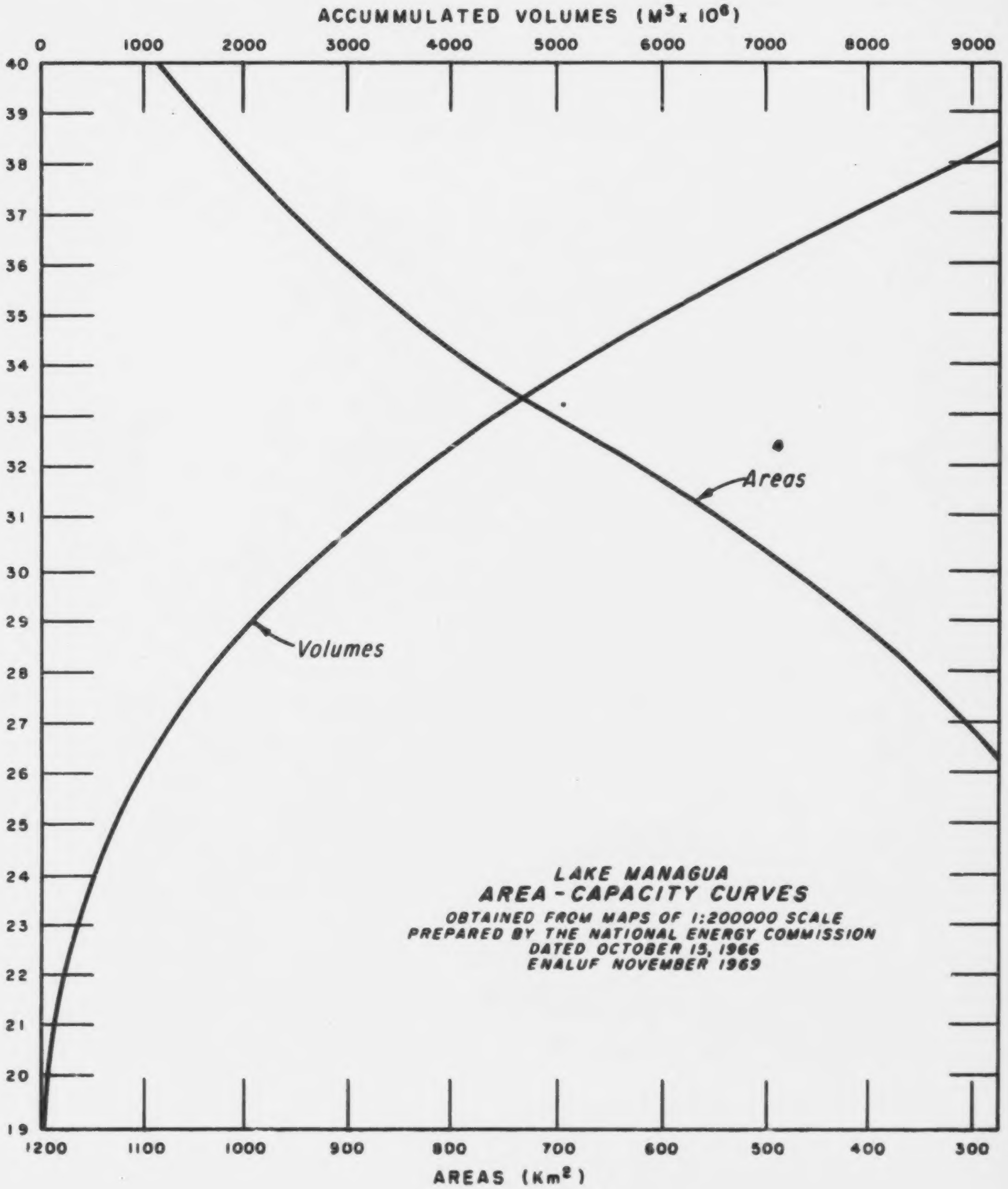

VOLUME (MMC)
160
120
80
40
0
35
0
25
20
15
10
5
0
ELEVATION - m
Volume
Areas
MIRAMAR DAMSITE
BRITO RIVER

FIGURE 10



TAMARINDO RESERVOIR
AREA-CAPACITY CURVES

FIGURE 11



LAKE MANAGUA
AREA - CAPACITY CURVES
OBTAINED FROM MAPS OF 1:200000 SCALE
PREPARED BY THE NATIONAL ENERGY COMMISSION
DATED OCTOBER 15, 1966
ENALUF NOVEMBER 1969

FIGURE 12

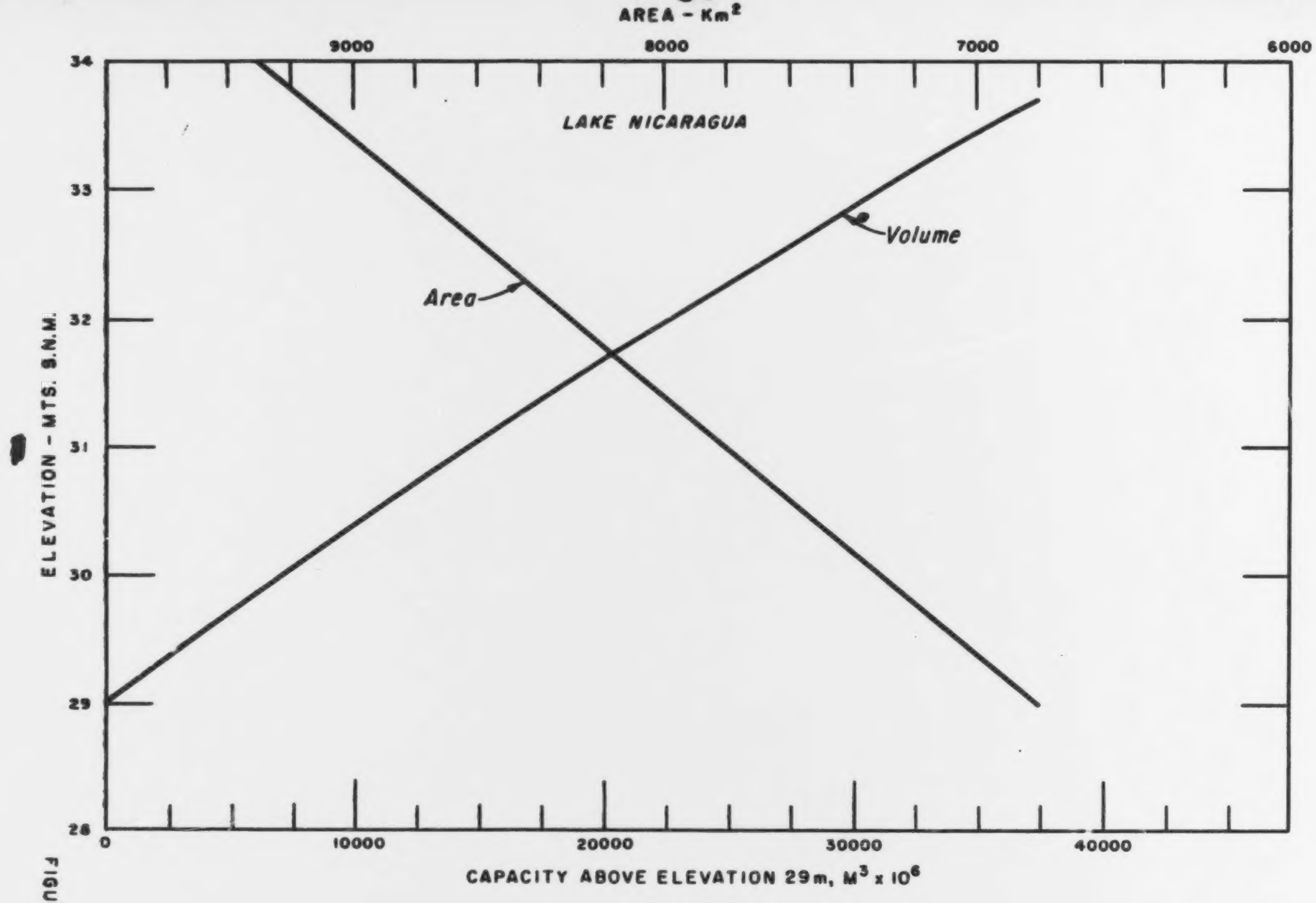

AREA - Km^2
9000
8000
7000
6000
LAKE NICARAGUA
Volume
Area
ELEVATION - MTS. S.N.M.
34
33
32
31
30
29
28
0
10000
20000
30000
40000
CAPACITY ABOVE ELEVATION 29m, M^3 x 10^6

FIGURE 13

MARCH 12, 1977 MEMORANDUM

To: Wayne V. Halliday, Director
Progecto Rio San Juan, Costa Rico - Nicaragua

From: Louis Y. Ehrlich, Engineer, Bureau of Reclamation, USDI (Retired)
Luis S. Palacios R., Ingeniero, Proyecto Rio San Juan

Design Storm for Tipitapa-Tamarindo and Rio Brito Proyectos Hidroelectricos, Nicaragua

The design storms presented in this memorandum are intended for use in spillway design flood studies for Lago Managua, for the proposed Tamarindo and Panaloya Reservoirs of Tipitapa-Tamarindo Project and for proposed reservoirs of Rio Brito Project.

A reduced maximum probable storm, taken as the average between maximum probable and 100-year levels, was used as the design storm for all of the drainages aforementioned for two major reasons: First, neither Lago Managua nor the proposed reservoirs offer any significant degree of hazard to populace in the event of a structural failure. Secondly, the lake and the proposed reservoirs have surface areas accounting for 17 to 19 percent of their drainage areas, and the potential for failure due to peak inflows is minimized by their relative superstorage.

The design storms were modeled from the temporal storm of Hurricane FIFI, 1974. Unit and total volumes are shown in the following tabulation:

	Area - km		Design storm	
Basin	Reservoir	Total	mm	$m^3 \times 10^6$
Lago Managua	1045 1/	5982 2/	678	4056
Tamarindo Reservoir	15	244	891	263
Panaloga Reservoir	39.4	371	518	192
Brito Reservoir	12.5	220	891	

1/ At 39.0 meters El.
2/ Exclusive of 543 km^2 transbasin diversion.

Previous Study

The watersheds of Lago Managua and Panoloya Reservoir were included as part of Rio San Juan Basin in the study. Spillway Design Storm for Sarapiqui and Machado High Dam Plans, Dicembre, 1975. Maximum probable and design storm precipitation totals were 537 mm and 421 mm, respectively, for Lago Managua watershed. The storm for this study was modeled from a transisthmus hurricane (IRENE, 1971) preceded by a temporal storm (EDITH, 1971) and was centered over Lago Nicaragua where maximum probable and design storm precipitation totals were 722 mm and 570 mm, respectively.

Basin Descriptions

Lago Managua. - Lago Managua basin, 5817 km^2 in area, is generally considered to be a closed basin since there is no surface outflow from the basin during most years. A transbasin diversion from Lago de Apanas to Rio Viejo adds 543 km^2 of controlled drainage area.

The lake contains about 9900 $m^3 \times 10^6$ and has about 1045 km^2 of surface area at elevation 39.0 meters, the average lake level for recent years. The lake is tributary to Lago Nicaragua through Rio Tipitapa at stages above 40.75 meters. Evaporation, consumptive use, and probably underflow generally hold the lake level below elevation 40.75 meters, and the last surface outflow occurred during 1944-45 for a period of 6 months. Prior to that time, the lake had surface outflow every year from 1933 through 1939.

Rio El Tamarindo. - Rio El Tamarindo basin contains about 244 km^2 of drainage area, primarily agricultural lands having gentle (less than 1 percent) slopes. The proposed reservoir would have about 15 km^2 of surface area, accounting for 6 percent of the total drainage basin.

Rio Brito. - The watershed of Rio Brito contains about 220 km^2 of drainage area, mainly rather steep drainage of the Pacific slope. The proposed reservoir would have about 12.5 km^2 of surface area, accounting for 6 percent of the total drainage.

Climate

The climate of Nicaragua is primarily influenced by the trade winds which provide an almost constant flow of maritime tropical air from the Caribbean

Sea. Precipitation from this airflow occurs on the eastern slopes of Sierra de Amerique leaving the western one-third of Nicaragua with a distinct November-May dry season.

The tradewinds are intermittently interrupted during two periods annually and heavy rains occur over the western portion of Nicaragua. Both periods result from the transit of the solar equator and subsequent passing of the doldrum belt.

In Lago Managua watershed, the vernal (northward) transit of the solar equator occurs about May 1 followed by the arrival of saturated air of the doldrums in June. During that month, considerable convective storm activity occurs with high intensity, short duration storms generally during the late evening hours.

Subsequent to the autumnal (southward) transit of the solar equator, about mid-August, the westward flow of the tradewinds is repetitiously interrupted by cyclonic storms and pressure depressions of the Caribbean Sea. During this period, the 3-month "hurricane season," the airflow pattern is often reversed and an inflow of maritime tropical air from the Pacific crosses Nicaragua in a northeastward direction. During these periods, widespread convection storm activity accounts for about one-half of the annual precipitation of Lago Managua basin and the adjacent coastal watersheds.

Hurricanes. - From 1886 through 1975, the tracks of 721 North Atlantic tropical cyclones have been plotted, an average of 8 per year. Only 20 of the storm centers reached Nicaragua during that period, an incident rate of less than one in 4 years.

The moderate hurricanes which crossed Nicaragua have dissipated into tropical depressions in their overland transit, often regenerating as hurricanes after reaching the warm water of the Pacific Ocean. These storms generally lacked the rotational velocity for the northward deflection common to major hurricanes and were carried across the Centroamerican Isthmus by the tradewinds. Intense precipitation occurs as the rotational velocity of these storms decreases, especially where the orographic effects of mountains are greatest. By the time the storm centers have reached the Pacific coastline, the precipitation potential has been largely dissipated.

Major hurricanes off the Caribbean coast of Nicaragua generally veer northward from their westward transit of the Caribbean Sean and often become great hurricanes as the impetus for rotation increases with longitudinal convergence. These storms, for reason of their low pressures, usually reverse the westward flow of the tradewinds across Nicaragua.

Temporals. - Temporals are general storms of the west coast resulting from the inflow of maritime Pacific air. These storms, usually several days in duration, cause widespread convective storm activity and occasionally produce rainfall throughout all areas of Nicaragua. Temporals may occur at nearly any time of the year when a combination of Pacific high pressure and Caribbean low pressure is sufficient to cause eastward airflow in opposition to the tradewinds. They are often influenced by more than one low pressure center, generally in sequence, making the termination of one storm to be indistinguishable from the beginning of the next. Although these storms often result from Caribbean lows without the presence of a cyclonic storm, the greatest temporals have always been associated with hurricanes.

Temporal Storm of 1908

Hurricane No. 7, 1908 (October 15-18), crossed the coastline of Nicaragua near Puerto Cabeza on October 18. Hurricane No. 7 degenerated to a tropical depression over Rio Coco watershed of Honduras and Nicaragua on October 19.

On October 18, a 3-day torrential rainfall began over Lago Managua watershed accompanied by a sudden increase in lake stage. The lake stage rose 1.83 meters over a period of 8 days with the largest increase, 0.64 meters, occurring on the first day of the storm. Net storage gain is shown by the following tabulation:

Period	Date	Meters	Avg. m^3/s	$m^3 \times 10^6$
1-day	October 18	0.64	7400	670
3-day	October 18-21	1.33	5100	1400
5-day	October 18-23	1.65	3700	1700
8-day	October 18-26	1.83	2650	1900

The 8-day volume accounts for about 325 mm of runoff from the watershed. With infiltration and probable outflow considered, the precipitation would have totalled more than 400 mm.

Maximum precipitation over Lago Managua watershed began simultaneously with the landfall of Hurricane No. 7 on the Caribbean coast of Nicaragua, indicating the storm to be a temporal of the hurricane. The short (3-day) duration of the storm is attributable to the degeneration of Hurricane No. 7 on October 19.

Temporal of GLADYS, 1968

Hurricane GLADYS, October 13-21, 1968, became a tropical cyclone in the western Caribbean Sea on October 13, 1968. The center moved generally northwestward and was about 200 km from Cabo Gracias a Dios on October 14. The center then moved northward, crossing Cuba on October 16 and was about 150 km from the west coast of Florida on October 18. The hurricane then moved northeastward across Florida causing five deaths and $6.7 million in damage. GLADYS was less than a great hurricane despite those disaster levels. The maximum sustained wind velocity was only 145 km/h and the lowest central pressure was 965 millibars.

The temporal of GLADYS began on October 13 while the hurricane was in development stage and continued through October 18 when the eye crossed the Florida coastline. During those 6 days, more than 400 mm of precipitation was recorded at several stations on the coast of Nicaragua. Satellite photographs of the temporal showed the convergent air pattern between the Pacific coast and the eastern periphery of GLADYS.

Temporal of IRENE, 1971

Hurricane IRENE, September 11-20, 1971, began as a tropical depression off the coast of Africa on September 7 and reached tropical storm strength in the western Caribbean on September 17. The storm developed a discernible eye with spiral bands crossing the Centroamerican Isthmus on September 18, indicating the temporal storm. IRENE was upgraded to a hurricane on September 18, and the center crossed Nicaraguan coastline about 65 km south of Bluefields on the morning of September 19. The eye of IRENE was observed on the eastern shore of Lago Nicaragua late on September 19, and the storm rapidly degenerated to a tropical depression. On the morning of September 20 the center of the storm crossed the west coast of Nicaragua into the Pacific Ocean about 80 km west of Managua. The storm immediately regained strength and was renamed Pacific Hurricane OLIVIA, September 20-30, 1971. The maximum sustained wind velocity of IRENE was about 75 km/h and lowest central pressure was 989 millibars.

Heavy precipitation on the west coast of Nicaragua began on September 18, prior to landfall of IRENE, and continued through September 20 when the storm entered the Pacific Ocean. Precipitation over Lago Nicaragua basin averaged 160 mm. The portions attributable to temporal and degenerating storm phases were not determinable.

Temporal of Hurricane FIFI, 1974

The temporal of Hurricane FIFI, September 14-22, 1974, was selected as the model for design storms for Lago Managua and Pacific Coast watersheds of Nicaragua. Precipitation for this storm is shown on plates .

Hurricane FIFI developed as a convective mass off the African coast on September 8, 1974, and became a well-organized tropical depression south of Haiti on September 15, a tropical storm south of Jamaica on September 16, and a hurricane about 400 km east of Isle de Cisme on September 17. The eye of FIFI moved westward just off the north coast of Honduras and made landfall in Belize on September 19. The storm dissipated in its overland transit of Belize and Mexico but immediately regenerated to become Pacific Hurricane ORLENE, September 20-24, 1974. FIFI was not a great hurricane despite the loss of 8,000 lives in Honduras. The maximum sustained win' velocity was 150 km/h and lowest central pressure was 971 millibars.

The temporal of FIFI began on September 16 and lasted through September 21. Flooding in El Salvador, southern Hondouras, and western Nicaragua was severe. More than 500 mm of precipitation was recorded at some weather stations in Lago Managua drainage.

Storm Adjustment

Precipitation of the temporal of Hurricane FIFI was adjusted for wind velocity and for potential precipitable water to achieve storm maximization. Adjustment factors found are as follows:

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Level	Adjustment
100-year storm	1.72
Probable maximum storm	3.12
Spillway design storm 1/	2.42

1/ Average of 100-year and PMP values.

The 100-year adjustment was calculated using the convective cell principle where moisture availability is assumed to be directly proportional to the velocity of the air which carries moisture from the sea to the land area. Central pressure of Hurricane FIFI was adjusted to 889 millibars, the 100-year level for North Atlantic hurricanes (figure 1). The air velocity is assumed to be proportional to the square root of the pressure gradient between the seacoast and the eye of the parent hurricane. Since no lateral transposition of the storm path was employed, distance from the seacoast to the eye of the hurricane was unchanged and the recorded and 100-year pressure differences were directly applied without calculation of gradient, as follows:

	Observed	Adjusted
Base sea level pressure, mbar	1013	1013
Central pressure, mbar	971	889
Difference, mbar	42	124
Ratio to observed difference	1.00	2.95
Velocity adjustment 1/	1.00	1.72

1/ 100-year storm value.

The temporal of FIFI, 1974, adjusted to the 100-year level, was maximized with respect to potential precipitable water to obtain probable maximum precipitation (PMP). The adjustment was calculated using saturated air values for observed and potential dewpoints (figure 2). Calculated sea level dewpoint at Las Mercedes and maximum recorded sea water temperature at Puerto Corinto were used as observed and potential dewpoints, respectively as follows:

	Observed	Adjusted
Sea level dewpoint, °C	22.4	29.6
Precipitable water, mm	64.5	117
Ratio to observed	1.0	1.81

Application of the combined adjustments to the observed precipitation resulted in the following values:

Basin	Precipitation, millimeters			
	Observed	100-year	PMP	Design
Lago Managua, Land Area	294	506	917	711
Lago Managua, Lake Area 1/	214	368	668	518
Lago Managua, Total	280	482	874	678
Rio Tamarindo and Rio Brito	368	633	1148	891

1/ Includes Rio Tipitapa.

Design Storm Distribution

Hourly precipitation for the design storms was obtained from recorded hourly precipitation during the temporal of FIFI, 1974, with adjustment for storm duration. The storm duration was reduced to a period of 3 days to coincide with historical durations for storms that have passed through or adjacent to western basins of Nicaragua.

Duration of temporals in Nicaragua is distinctly related to the distance between the Pacific Ocean and the path of the parent tropical cyclone. Hurricane GLADYS 1968, which passed nearly 800 km from the Pacific coast of Nicaragua, produced a temporal storm of nearly 6 days' duration and Hurricane FIFI 1974, passing some 450 km from the coastline, produced a temporal of about 4 days' duration. Conversely, Hurricane No. 7 1908 and Hurricane IRENE 1971, both crossing Nicaragua adjacent to Lago Managua, had temporals of only 3-day duration. The 3-day duration was adopted on the premise that the path of FIFI could have occurred some 3° south of the historic path.

The spillway design storms, distributed hourly, are presented in tables 1, 2, and 3.

Application

The 72-hour design storms presented in tables 1 through 3 are intended for direct application without rearrangement of incremental values since neither lateral transposition nor reorientation of the parent storm were employed.

Antecedent Condition

Storm Sequence. - Temporals, resulting from distant parent storms, often overlap so that the beginning of one temporal is indistinguishable from the end of a preceding storm. Analysis of the tracks of tropical cyclones which have occurred during the past 90 years showed numerous occasions where storm tracks have crossed at varying intervals. The shortest interval, about 50 hours, occurred during 1931 (figure 3). The probability of two tropical cyclone paths being positioned to initiate temporals would be similar, and figure 3 can be considered illustrative of the lag period between the beginnings of two temporals. Thus, the occurrence of an average magnitude temporal preceding or extending into the design storm period is probable.

Drainage Basins. - A wet antecedent moisture condition (condition III) is recommended for use in the design flood studies of Lago Managua basin and the Pacific slope basins of Nicaragua. This would reflect the probability of a preceding, lesser magnitude storm beginning 5 days prior to the spillway design storm, a one in 8-year event.

Reservoirs. - For the aforementioned reasons, it is recommended that the proposed reservoirs of the Tipitapa-Tamarindo and Brito Projects be assumed to be of their maximum controlled stage (without spillway discharge or wasteway release) at the beginning of routing studies for the spillway design flood. The maximum controlled level for Lago Managua would be about 39.5 meters with Tipitapa-Tamarindo Project, 40.75 meters without the project.

Table 1. - Spillway Design Storm - Millimeters
Cuenca Lago Managua - Land Area

Hour	mm	Hour	mm	Hour	mm
1	9	25	124	49	538
2	13	26	137	50	540
3	13	27	169	51	557
4	13	28	190	52	570
5	14	29	231	53	577
6	19	30	262	54	592
7	26	31	287	55	618
8	28	32	328	56	627
9	34	33	353	57	637
10	50	34	404	58	648
11	52	35	437	59	650
12	60	36	455	60	656
13	71	37	462	61	659
14	75	38	464	62	664
15	75	39	466	63	667
16	75	40	467	65	670
17	75	41	469	65	673
18	75	42	486	66	683
19	75	43	500	67	693
20	77	44	508	68	696
21	78	45	513	69	697
22	83	46	515	70	705
23	92	47	519	71	711
24	104	48	527	72	711

Distributed with respect to total precipitation at Jinotega, Unan, San Francisco del Carnicero.

Table 2. - Spillway Design Storm - Millimeters
Lago Managua - Rip Tipitapa

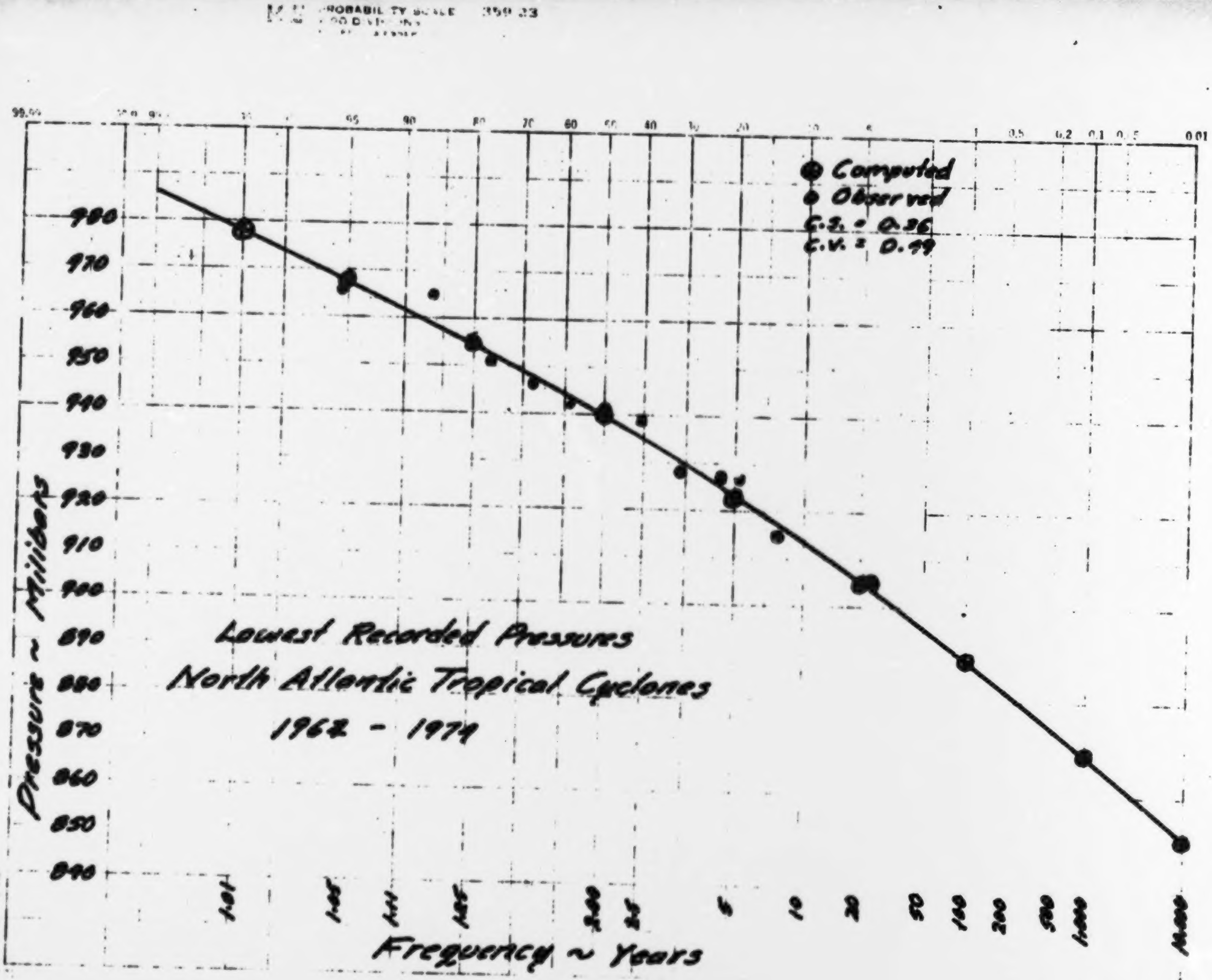
Hour	mm	Hour	mm	Hour	mm
1	15	25	127	49	417
2	22	26	141	50	418
3	22	27	158	51	426
4	23	28	173	52	435
5	25	29	227	53	443
6	25	30	252	54	448
7	25	31	268	55	454
8	25	32	280	56	463
9	35	33	295	57	463
10	65	34	335	58	479
11	67	35	356	59	481
12	70	36	367	60	481
13	83	37	371	61	481
14	91	38	371	62	482
15	92	39	373	63	483
16	92	40	373	64	489
17	92	41	373	65	489
18	92	42	402	66	491
19	92	43	413	67	492
20	93	44	414	68	492
21	93	45	414	69	494
22	95	46	414	70	509
23	101	47	415	71	518
24	108	48	417	72	518

Distributed with respect to recorded values at San Francisco del Carnicero.

Table 3. - Spillway Design Storm - Millimeters
Rio El Tamarindo and Rio Brito

Hour	mm	Hour	mm	Hour	mm
1	7	25	317	49	723
2	7	26	319	50	723
3	21	27	325	51	724
4	27	28	341	52	732
5	55	29	371	53	733
6	65	30	425	54	749
7	66	31	464	55	759
8	66	32	472	56	761
9	66	33	521	57	781
10	66	34	535	58	819
11	67	35	552	59	822
12	71	36	574	60	841
13	78	37	591	61	842
14	99	38	607	62	843
15	139	39	620	63	856
16	174	40	642	64	869
17	185	41	656	65	878
18	192	42	680	66	882
19	232	43	693	67	882
20	296	44	715	68	882
21	315	45	715	69	886
22	316	46	716	70	887
23	317	47	719	71	891
24	317	48	722	72	891

Distributed with respect to recorded precipitation at Playa Grande.



Lowest Recorded Pressures
North Atlantic Tropical Cyclones
1962 - 1979

FIGURE I

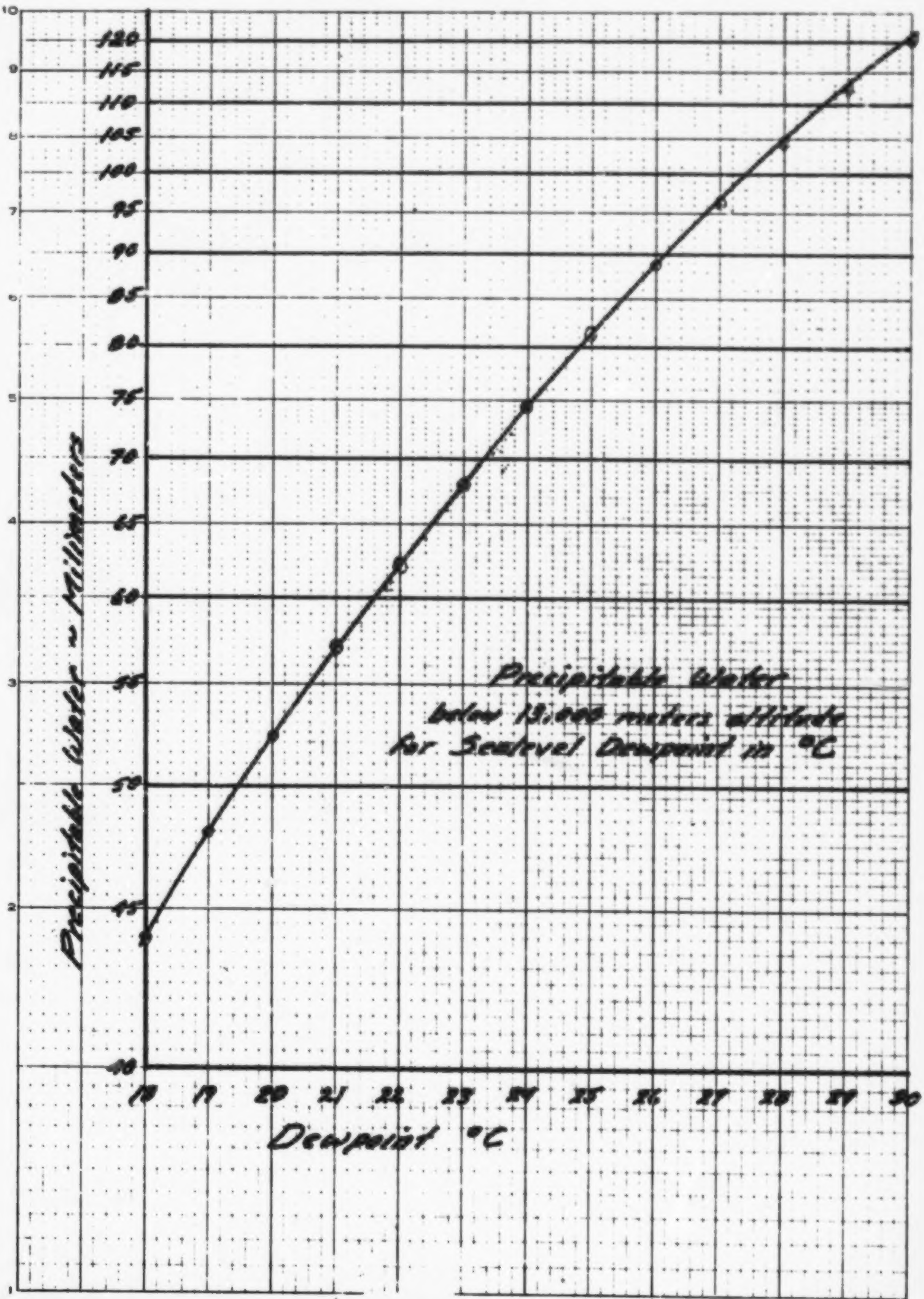
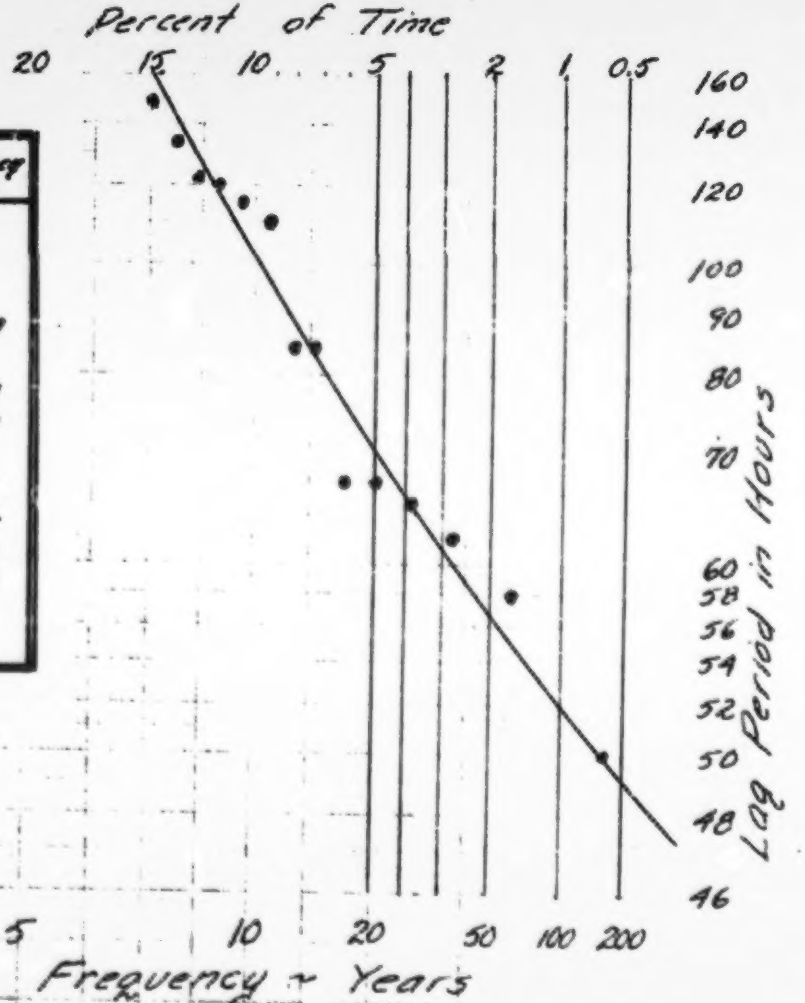

NO. 340-L110 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
1 CYCLE X 10 DIVISIONS PER INCH
EUGENE DIETZGEN CO.
Precipitable Water ~ Millimeters
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
18
19
20
21
22
23
24
25
26
27
28
29
30
Dewpoint °C
Precipitable Water
below 13,000 meters altitude
for Sealevel Dewpoint in °C

FIGURE 2

Year	Lag Hours	% of Time	Frequency Years
1931	50	0.6	180
1945	58	1.7	60
1933	62	2.8	36
1901	65	3.9	25.7
1922	67	5.0	20
1926	67	6.1	16.4
1971	84	7.2	13.8
1886	84	8.3	12
1958	110	9.4	10.6
1933	115	10.6	9.5
1928	120	11.7	8.6
1937	122	12.8	7.8
1954	134	13.9	7.2
1931	149	15.0	6.7



90 years of Record

14 Least Values Shown

Lag Time in Hours for 2 storm centers Crossing the Same Point

FIGURE 3

United States Department of the Interior
BUREAU OF RECLAMATION
ENGINEERING AND RESEARCH CENTER
P.O. BOX 25007
BUILDING 67, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY REFER TO: 751

OCT 31 1977

167.

Memorandum

To: Project Engineer, Tipitapa-Tamarindo Prefeasibility Project, Nicaragua (Wayne Halliday, Denver)

From: Chief, Division of Planning Coordination

Subject: Design Storms for the Tipitapa-Tamarindo and Rio Brito Projects, Nicaragua

Recommended design storms for Libano, Tamarindo, and Miramar Damsites, Tipitapa-Tamarindo and Rio Brito Projects, Nicaragua are provided in the design storm study by Clarence E. Everson, Flood Section, subject as above, dated September 1, 1977, 3 copies of which are enclosed.

This study was prepared in support of the project following our review and conclusion that the March 12, 1977 design storm study by Louis Y. Ehrlich was not fully adequate because of questionable assumptions and departures from acceptable practices in the derivation of design storms.

W W Reedy

Enclosure

Copy to: Commissioner, Attention: 1300
Stanley Larsen, Project Engineer, Tipitapa-Tamarindo Project, Nicaragua, c/o American Embassy, APO New York 09885 (w/enc)

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ENGINEERING AND RESEARCH CENTER
Building 67, Denver Federal Center
Denver, Colorado 80225
September 1, 1977

Memorandum

To : Head, Flood Section

From : Clarence E. Everson

Subject: Design Storms for Libano, Tamarindo, and Miramar Damsites, Tipitapa-Tamarindo and Rio Brito Projects, Nicaragua

Introduction

The design storms for Libano, Tamarindo, and Miramar damsites presented in reference 1 were reviewed and found to be unsupportable because of questionable assumptions and departures from generally acceptable practices in the derivation of design storms. Therefore, design storms are derived in this study which are recommended for use in place of those provided in reference 1.

Basin Descriptions

Libano damsite is located on the Rio Tipitapa about 5-1/2 km below Lake Managua. The drainage area above Libano damsite is 5982 km^2. It includes Lake Managua which has a water surface area of 1045 km^2 at 39 m elevation. The land area is 4937 km^2. Elevations range from 40 m at the damsite to 1688 m in the upper part of the basin. The average elevation of Lake Managua is 39 m. An outline of the drainage area is shown in plate 1.

Tamarindo damsite is located on the Rio Tamarindo which drains westward to the Pacific Ocean. It is about 5 km from Puerto Somoza on the Pacific Coast. It is about 17-1/2 km from the western part of Lake Managua. Elevations range from about 20 m at the damsite to 333 m (El Tablon) in the southern part of the basin. The drainage area is 244 km^2. An outline of the drainage area is included in plate 1.

Miramar damsite is located on the Rio Brito which drains to the Pacific Ocean at approximately 11°20'N. The damsite is about 6 km from the mouth of the Rio Brito. Elevations range from about 10 m at the damsite to 405 m in the northwestern part of the basin. The drainage area is 222 km^2.

Storm Climatology

Tropical storms and hurricanes occur in the western Caribbean on an average of two per year. Some of them originate in the western part of the Caribbean and some track into the area from the east. Many of the hurricanes in the western Caribbean track northward to the Gulf of Mexico. However, some track westward and strike Honduras, Nicaragua, and Costa Rica. An average of one hurricane in 12 years since 1871, has directly hit Nicaragua. Including those which touch only the northeastern corner of Nicaragua, the average is one hurricane in 5 years. Sometimes they track all the way across Nicaragua to the Pacific as happened in September 1911. A tropical storm in December 1887 tracked westward across Costa Rica to the Pacific. Hurricane Martha struck Panama in December 1969. It was the first hurricane to hit Panama in 99 years of record up to that time and proved that they can produce severe rainfall and floods even in the southernmost country of Central America.

Strong southwest to west winds on the Pacific Coast of Nicaragua can occur with western Carribean hurricanes. Such a situation which is locally known as a temporal can produce considerable rainfall, especially in the Pacific coastal region.

The mean position of the intertropical convergence zone advances northward in the spring and reaches its northernmost position over southern Mexico in midsummer. It retreats southward in the fall and is south of the equator in winter. It is over Nicaragua in June during its northward movement and in September and October as it moves southward. Squalls develop in this zone and produce the maximum monthly rainfall observed in the Pacific coastal region of Nicaragua in June and again in September and October. Severe thunderstorms can occur in such situations and heavy rainfall can persist for several days.

Derivation of the Design Storm for Libano Damsite

The most severe rainfall above Libano damsite would be produced by a tropical storm or hurricane. No major hurricane rainfall cases in Nicaragua have been documented. Hurricanes of recent years for which rainfall data are available are not considered representative of major storms which are necessary for use in design storm derivation. Therefore, the use of major storms from a region similarly exposed to tropical storms and for which the documentation of storm rainfall covers a long period of record is considered essential in the design storm derivation for Libano damsite.

The region in Texas, which is located at about the same distance from the Gulf Coast as Libano damsite is from the Caribbean coast fits this requirement reasonably well. The coastlines correspond in length, and the coastline exposure relative to tropical storm tracks is similar. The greater frequency of tropical storms which affect Texas serves to increase significantly the storm experience base and consequently the attainment of a design storm which is both adequate and reasonable.

Various tropical-type storms were reviewed and two were chosen for transposition. One occurred in the vicinity of Thrall, Texas, on 8-10 September 1921. The location of the storm is about 240 km inland from the coast. The precipitation pattern was transposed to give the most critical centering above Libano damsite as shown in plate 3. The storm rainfall was adjusted for moisture potential and inflow barrier as shown in plate 4. This was combined with the fit factor to give a total adjustment of 0.82 as shown in plate 4. A similar transposition was made of the precipitation pattern for the storm of 27 June to 1 July 1899 in the vicinity of Hearne, Texas, which also is about 240 km from the coast. The transposed pattern is shown in plate 5. The distribution and adjustment for this storm are shown in plate 6. The adjusted precipitation depth-duration values from these two storms for the total drainage area above Libano damsite were enveloped to provide the design storm precipitation-depth duration curve in plate 7. The total area above Libano damsite was subdivided into two subbasins; one comprises the land area and the other the water surface area of Lake Managua. The design storm precipitation depth-duration curves for these two subbasins are shown in plates 8 and 9. The precipitation patterns were extended over the drainage area above Tamarindo damsite and adjusted precipitation depth-duration values were included in plates 4 and 5. These values were used in plate 10 to give the concurrent precipitation depth-duration curve for the area above Tamarindo damsite. It is not the design storm for Tamarindo damsite but the storm which is concurrent with the design storm for Libano damsite.

The design storms for Libano damsite and the land and lake surface subbasins are tabulated in table 1. Also included in table 1 is the concurrent storm (not the design storm) for Tamarindo damsite. There are no restrictions on rearrangement of the design storm for Libano damsite.

Derivation of the Design Storm for Tamarindo and Miramar Damsites

The severe storm of 24-31 October 1960 in the northwest coastal area of Nicaragua provides the basis for the design storm for Tamarindo and Miramar damsites. A probable maximum thunderstorm could occur within a storm situation of this type in which the intertropical convergence zone with severe squalliness and onshore flow of unstable air persists for several days. Therefore, a probable maximum thunderstorm is combined with the 24-31 October 1960 storm.

The October 1960 storm is described in reference 2 as producing record rainfall in northwestern Nicaragua. A pattern of the 8-day rainfall is included in reference 2. Total storm rainfall exceeded 1200 mm and the 1200-mm isohyet covered an area more than three times the area above either Tamarindo or Miramar damsites. Daily rainfall records for Ingenio San Antonio located in the heavy rainfall area were obtained from Nicaragua. The total storm rainfall was 1205 mm. This value was considered appropriate for the transposed total amount for both drainage areas. The distribution and adjustment of rainfall are shown in plate 11.

The type of situation which produced the 8-day storm in October 1960 could also produce the extreme thunderstorm rainfall in the Pacific coastal region of Nicaragua. Squalls forming in the convergence zone over the warm Pacific waters and passing over increasingly warmer waters as they move toward the coast could produce a probable maximum thunderstorm event. Therefore, it is prudent to include such a thunderstorm with the design storm. In the absence of adequate thunderstorm rainfall data in the area, it is necessary to judge the thunderstorm potential on the basis of studies in other areas. The recent study by the Hydrometeorological Branch of the U.S. National Weather Service on probable maximum thunderstorm rainfall in the southwestern United States (reference 3) is used to provide a reasonable estimate of the thunderstorm potential for Tamarindo and Miramar damsites. A value of 318 mm was chosen as the most intense 1-hour point value of probable maximum precipitation in the southwest United States. This value was reduced for area and time distribution factors applied to get hourly values for a 6-hour thunderstorm according to the procedures in reference 3. The resulting probable maximum thunderstorm is as follows:

Duration (hours)	Probable maximum thunderstorm precipitation (mm) for Tamarindo and Miramar damsites (244 and 222 km^2, respectively)
1	156
2	223
3	272
4	304
5	334
6	363

The above values for probable maximum thunderstorm precipitation and the transposed and adjusted precipitation values in plate 11 for the storm of 24-31 October 1960 were enveloped as shown in plate 12 to provide the design storm precipitation depth-duration curve for Tamarindo and Miramar damsites. A tabulation of design storm precipitation depth-duration values is provided in table 2. There are no restrictions on the rearrangement of this design storm.

Design Storm Comparisons

Design storm comparisons are shown in table 3. The design storm for Tamarindo and Miramar damsites compares favorably with probable maximum precipitation for the Pacific side of eastern Panama from reference 4. The comparison between the design storm for Libano damsite and probable maximum precipitation for the Panama Canal basin from reference 5 is reasonably good.

Recommendations

The recommended design storm for Libano damsite is given in table 1. The associated design storm precipitation depth-duration curve is given in plate 7. There are no restrictions on rearrangement of this design storm. This design storm evaluated over the two subbasins, one for the land area and the other for the Lake Managua water surface area at 39 m, is included in table 1 and in plates 8 and 9. Also, the concurrent storm above Tamarindo damsite is included in table 1 with the depth-duration curve shown in plate 10.

The design storm as given in table 2 is recommended for Tamarindo damsite and for Miramar damsite. The associated design storm precipitation depth-duration curve is shown in plate 12. There are no restrictions on rearrangement of this design storm.

Clarence E. [illegible]

I Concur: F. A. Bertle
Head, Flood Section 10/25/77

I Concur:
M. Leon Hy[illegible]
Chief, Hydrology Branch

I Concur: OCT 31 1977
W. W. Reedy
Chief, Division of Planning
Coordination

References

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2. The Water Resources of Nicaragua, Final Technical Report, Volume III, Tax Improvement and Natural Resources Inventory Project, Nicaragua, Prepared under the Supervision of Parsons Corporation in Joint Venture with Marshall and Stevens, Incorporated and International Aero Service Corporation, Operations Consultant, undated (but believed to have been published about 1971 or 1972)

3. Probable Maximum Thunderstorm Precipitation Estimates, Southwest States (U.S.), John T. Riedel and E. Marshall Hansen, Hydrometeorological Branch, National Weather Service, Washington, D.C. 1972 (draft)

4. Probable Maximum Precipitation over Eastern Panama, and Northwest Columbia, Hydrometeorological Branch, Office of Hydrology, U.S. Weather Bureau, September 1965

5. Maximum Possible Precipitation over the Panama Canal Basin, Hydrometeorological Report No. 4, Hydrometeorological Section, U.S. Weather Bureau, 1943

List of Tables

1. Design Storm for Libano damsite (total area, sub-basin land area only, subbasin Lake Mangua surface area only), and concurrent storm above Tamarindo damsite

2. Design Storm for Tamarindo and Miramar damsites (same design storm for both damsites)

3. Comparative design storms

List of Plates

1. Basin outline for Libano damsite and Tamarindo damsite
2. Basin outine for Miramar damsite
3. Precipitation pattern, transposed Thrall, Texas storm of 8-10 September 1921, Libano and Tamarindo damsites
4. Distribution and adjustment, transposed Thrall, Texas storm of 8-10 September 1921, Libane and Tamarindo damsites
5. Precipitation pattern, transposed Hearne, Texas storm of 27 June to 1 July 1899, Libano and Tamarindo damsites
6. Distribution and adjustment, transposed Hearne, Texas storm of 27 June to 1 July 1899, Libano and Tamarindo damsites
7. Design storm precipitation depth-duration curve, Libano damsite, total drainage area
8. Design storm precipitation depth-duration curve, Libano damsite, land area only
9. Design storm precipitation depth-duration curve, Libano damsite, Lake Managua surface area only
10. Precipitation depth-duration curve for the storm above Tamarindo damsite concurrent with the design storm for Libano damsite
11. Distribution and adjustment, transposed northwest Nicaragua coastal storm of 24-31 October 1960, Tamarindo and Miramar damsites
12. Design storm precipitation depth-duration curve, Tamarindo and Miramar damsites

Table 1. - Design storm for Libano damsite, Nicaragua.

Duration (hours)	Total area (land and lake surface area) 5982 km^2		Land area (excludes surface of Lake Managua) 4937 km^2		Surface area of Lake Maragua (at elevation 39 m) 1045 km^2		Concurrent storm above Tamarindo damsite 244 km^2	
	Precipitation (mm)	Increment (mm)	Precipitation (mm)	Increment (mm)	Precipitation (mm)	Increment (mm)	Precipitation (mm)	Increment (mm)
3	142	142	150	150	104	104	205	205
6	223	81	232	82	183	79	290	85
9	287	64	295	63	250	67	358	68
12	342	55	348	53	314	64	415	57
15	390	48	394	46	371	57	463	48
18	435	45	437	43	425	54	507	44
21	478	43	478	41	478	53	540	33
24	518	40	516	38	528	50	567	27
27	554	36	550	34	573	45	589	22
30	584	30	579	29	608	35	607	18
33	610	26	604	25	638	30	620	13
36	632	22	626	22	660	22	632	12
39	651	19	645	19	679	19	640	8
42	667	16	661	16	695	16	648	8
45	682	15	676	15	710	15	653	5
48	695	13	689	13	723	13	658	5
51	708	13	702	13	736	13	662	4
54	720	12	714	12	748	12	665	3
57	730	10	725	11	754	6	667	2
60	740	10	736	11	759	5	669	2
66	750	10	746	10	769	10	672	3
72	760	10	756	10	779	10	675	3
78	765	5	761	5	784	5		
84	768	3	764	3	787	3		
90	771	3	767	3	790	3		
96	773	2	769	2	792	2	676	1

Table 2. - Design storm precipitation depth-duration values (mm) Tamarindo damsite, Nicaragua 244 km^2 and Miramar damsite (on Rio Brito), Nicaragua 222 km^2

Duration (hours)	Precipitation depth (mm)	Increment (mm)	Duration (hours)	Precipitation depth (mm)	Increment (mm)
1	156	156	45	809	27
2	223	67	48	836	27
3	272	49	51	863	27
4	304	32	54	890	27
5	334	30	57	916	26
6	363	29	60	942	26
7	386	23	63	968	26
8	406	20	66	994	26
9	425	19	69	1020	26
10	444	19	72	1045	25
11	461	17	78	1095	50
12	478	17	84	1144	49
13	492	14	90	1192	48
14	506	14	96	1240	48
15	520	14	102	1288	48
16	534	14	108	1335	47
17	547	13	114	1382	47
18	560	13	120	1428	46
19	571	11	126	1474	46
20	582	11	132	1520	46
21	592	10	138	1566	46
22	602	10	144	1612	46
23	611	9	150	1656	44
24	620	9	156	1695	39
27	647	27	162	1729	34
30	674	27	168	1757	28
33	701	27	174	1764	7
36	728	27	180	1771	7
39	755	27	186	1777	6
42	782	27	192	1783	6

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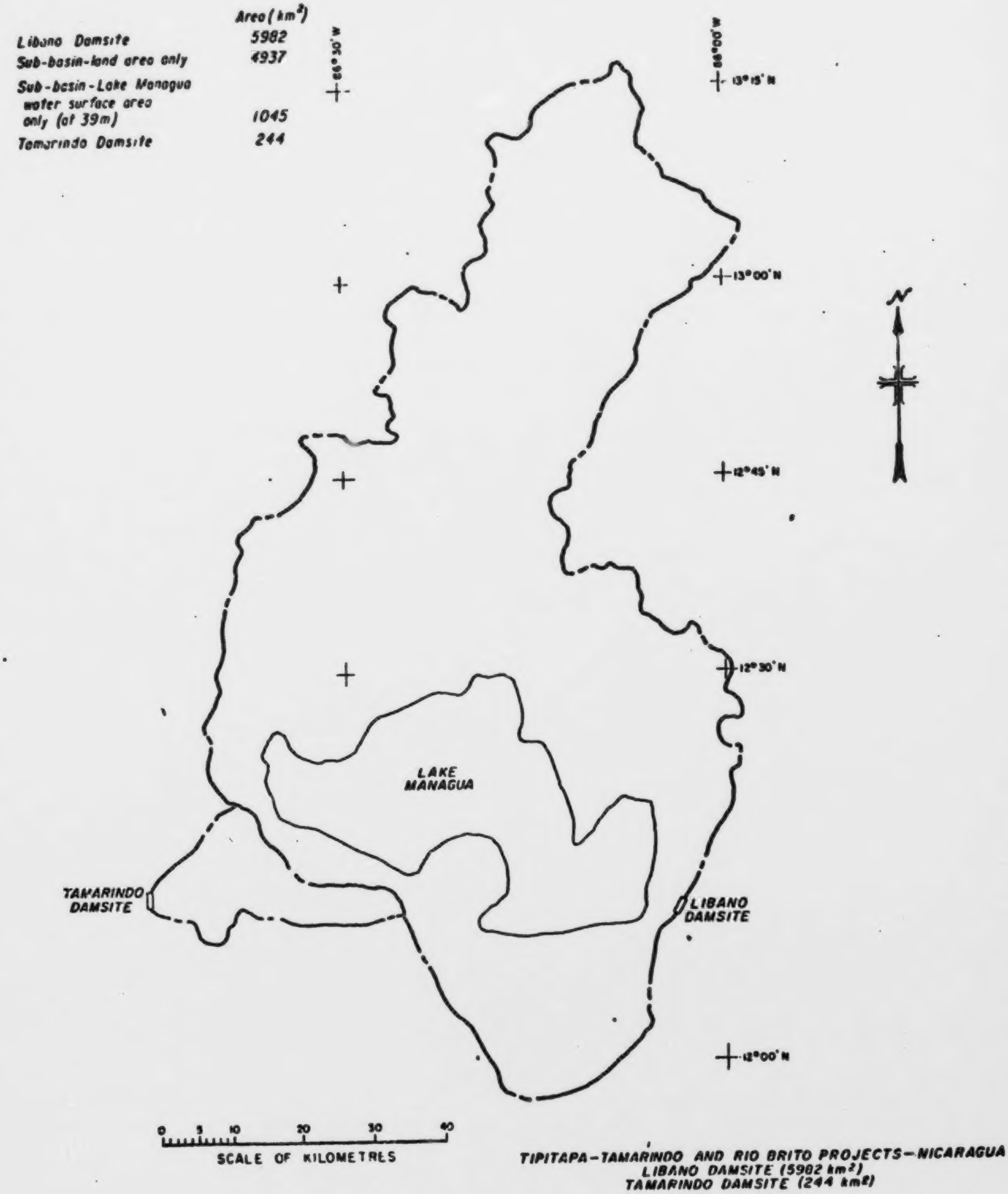
Table 3. - Design storm comparisons -
Precipitation depth - duration values (mm)

Duration (hours)	Recommended design storm for Tamarindo damsite 244 km^2 and for Miramar damsite (on Rio Brito) 222 km^2	Probable maxium precipitation on Pacific side of eastern Panama based on reference 4 244 km^2	Recommended design storm for total drainage area above Libano damsite 5982 km^2	Recommended design storm for the sub-basin comprising the land area only above Libano damsite 4937 km^2	Recommended design storm for the sub-basin comprising the lake surface area of Lake Managua (at el. 39 m) 1045 km^2	Recommended storm above Tamarindo damsite concurrent with the storm above Libano damsite 244 km^2	Probable maximum precipitation for the Panama Canal basin from reference 5 3424 km^2
6	363	356	223	232	183	290	257
12	478	462	342	348	314	415	356
24	620	614	518	516	528	567	472
48	836	779	695	689	723	658	599
72	1045	891	760	756	779	675	683
96	1240	990	773	769	792	676	742
120	1428	1076					795
144	1612	1162					843
168	1757						
192	1783						

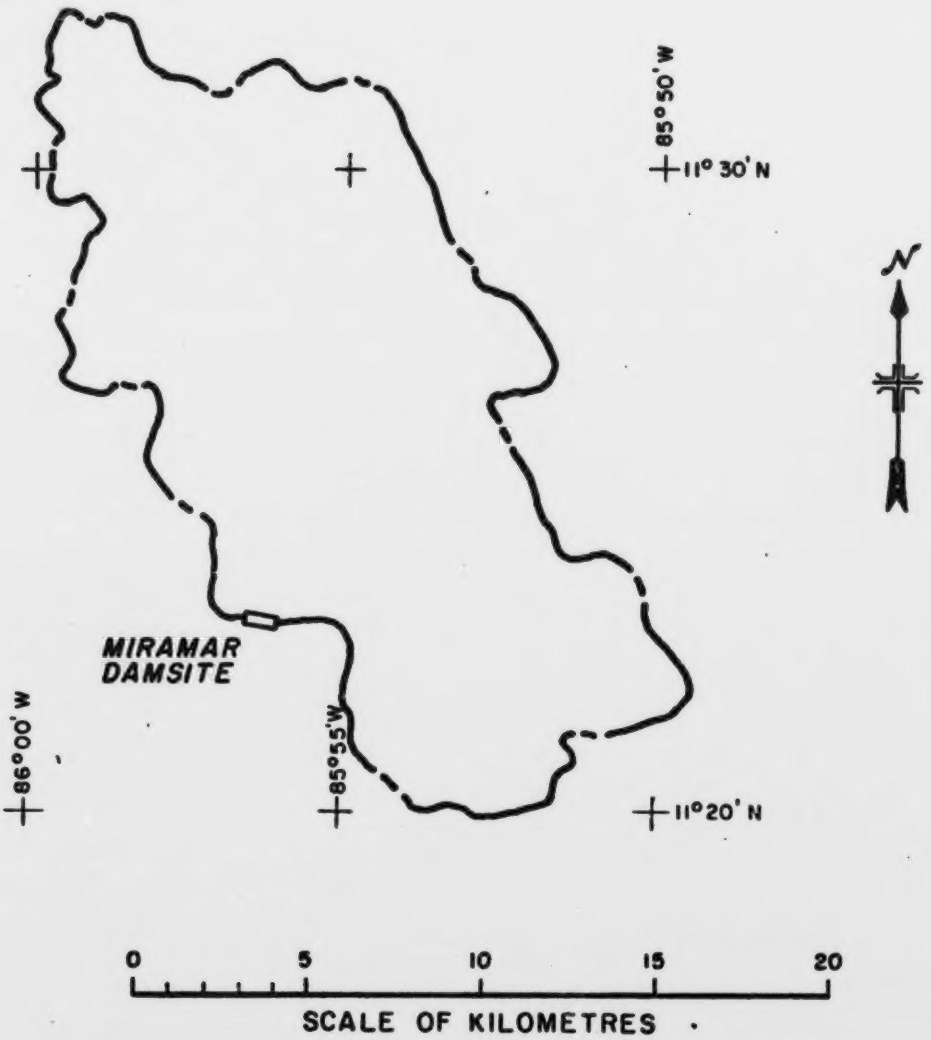

86°30' W
86°00' W
13°15' N
13°00' N
12°45' N
12°30' N
12°00' N
N
LAKE MANAGUA
TAMARINDO DAMSITE
LIBANO DAMSITE
0 5 10 20 30 40
SCALE OF KILOMETRES

	Area (km²)
Libano Damsite	5982
Sub-basin-land area only	4937
Sub-basin-Lake Managua water surface area only (at 39m)	1045
Tamarindo Damsite	244

TIPITAPA-TAMARINDO AND RIO BRITO PROJECTS-NICARAGUA
LIBANO DAMSITE (5982 km²)
TAMARINDO DAMSITE (244 km²)

BASIN OUTLINE

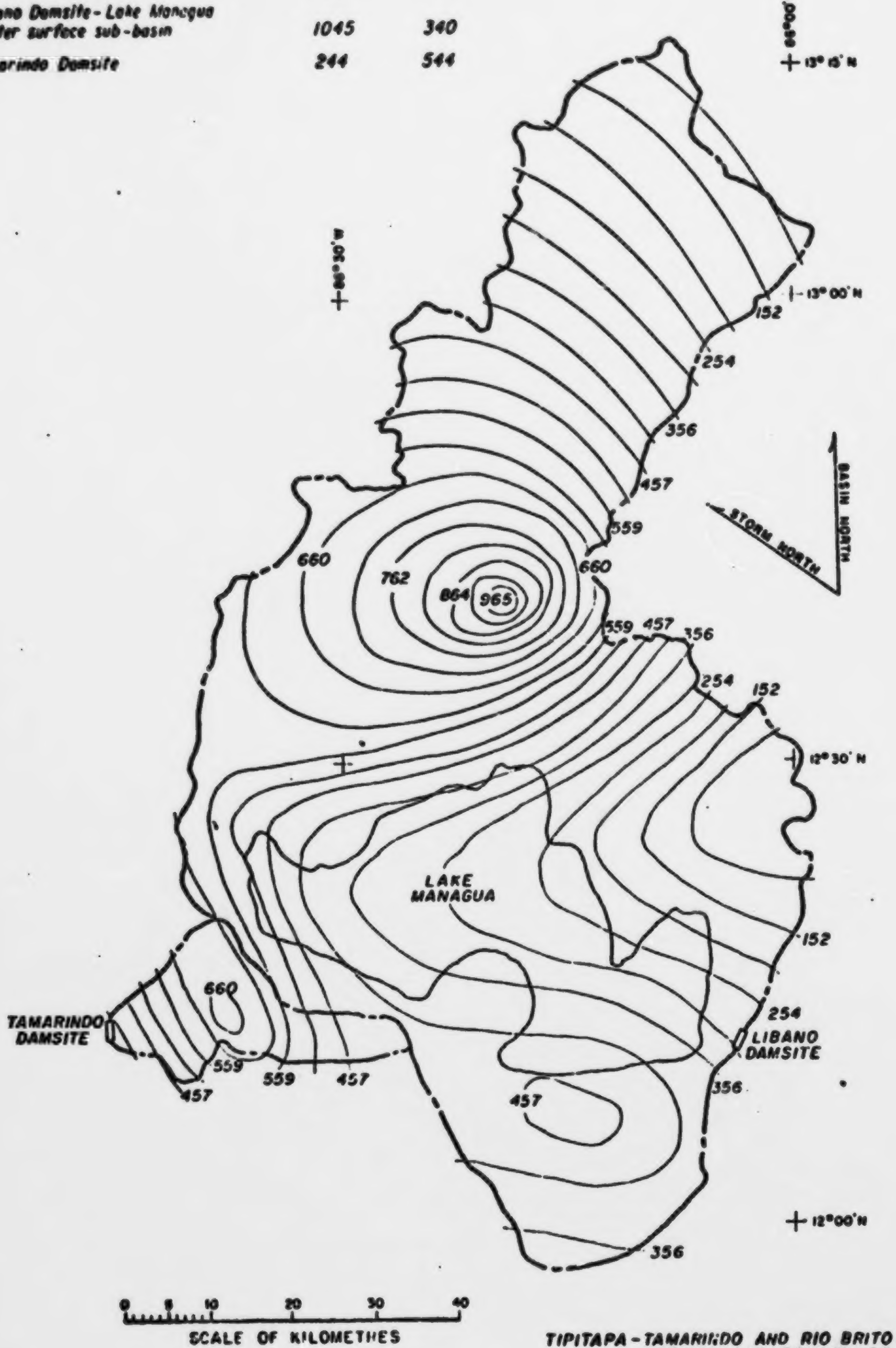
PLATE I


85°50'W
11° 30'N
N
MIRAMAR
DAMSITE
86°00'W
85°55'W
11°20'N
0
5
10
15
20
SCALE OF KILOMETRES

TIPITAPA–TAMARINDO AND RIO BRITO PROJECTS–NICARAGUA
MIRAMAR DAMSITE
BASIN OUTLINE
DRAINAGE AREA 222km²

PLATE 2

	Area (km²)	Average Precipitation (mm)
Libano Damsite - total basin	5982	417
Libano Damsite - land sub-basin	4937	432
Libano Damsite - Lake Managua water surface sub-basin	1045	340
Tamarindo Damsite	244	544


98°00'W
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98°30'W
13°00'N
152
254
356
457
559
660
BASIN NORTH
STORM NORTH
660
762
864
965
660
559
457
356
254
152
12°30'N
LAKE MANAGUA
152
660
TAMARINDO DAMSITE
254
LIBANO DAMSITE
559
457
559
457
457
356
12°00'N
356
0 5 10 20 30 40
SCALE OF KILOMETRES

TIPITAPA-TAMARINDO AND RIO BRITO PROJECTS - NICARAGUA
LIBANO AND TAMARINDO DAMSITES

ISOHYETAL PATTERN

STORM OF SEPTEMBER 8-10, 1921
CENTERED NEAR THRALL, TEXAS

PLATE 3

HDm-84 (6-76)
Bureau of Reclamation

SI METRIC

DISTRIBUTION AND ADJUSTMENT OF STORM PRECIPITATION

STORM NO. GM 4-12 **STORM DATE, LOCATION** 8-10 Sept 1921 Thrall, Texas
TRANSPOSED (X **) INPLACE (** ____ **) ABOVE** Libano & Tamarindo damsites, Nicaragua
DRAINAGE AREA (km²): TOTAL 5982 & 244 **CONTRIBUTING** ____

MAXIMUM OBSERVED PRECIPITATION DEPTH-DURATION VALUES (mm)

AREA (km²)	DURATION (HOURS)						
Libano damsite - Total area							
	6	12	18	24	30	36	48
5 982	272	381	475	500	516	523	528
Libano damsite - Land area only							
4 937	283	396	494	520	537	544	549
Libano damsite - Lake Managua surface area only							
1 045	223	312	390	410	423	429	433
Tamarindo damsite - Concurrent storm							
244	354	495	618	650	671	680	686

STORM DURATION (HOURS) 48 **ENDING TIME** 1200L 10 Sep 1921 **BASIN AVG PRECIP (mm)** 417

BASIS OF TIME DISTRIBUTION: Storm Studies - Pertinent Data Sheet, U.S. Corps of Engineers and U.S. Weather Bureau, 1946 for 5 982 km^2 (as shown in the top line). These values were multiplied by the ratio of the average storm precipitation (see remarks)

COMPUTATION OF FIT FACTOR: 417 : 528 = 0.79

OBSERVED STORM DEWPOINTS

STATION	ELEVATION	DURATION	ENDING	OBSERVED	SEA LEVEL(SL)
400 km south of Thrall, Texas					25.0

COMPUTATION OF MOISTURE ADJUSTMENT

OBSERVED STORM		ADJUSTED STORM	
MOISTURE SOURCE	Gulf of Mexico	MOISTURE SOURCE	Western Caribbean
SL DEWPOINT	25.0 °C	MAXIMUM SL DEWPOINT	27.8 °C
INFLOW BARRIER	200 m	INFLOW BARRIER	1 000 m
PRECIPITABLE WATER SL TO 12000m	81 mm	PRECIPITABLE WATER SL TO 12000 m	103 mm
PRECIPITABLE WATER SL TO 200 m	5 mm	PRECIPITABLE WATER SL TO 1 000 m	24 mm
NET PRECIPITABLE WATER	76 mm	NET PRECIPITABLE WATER	79 mm

MOISTURE ADJUSTMENT = 79 ÷ 76 = 1.04

SOURCE OF MAXIMUM SL DEWPOINT Avg sea temp based on Pub 700 USN Oceanographic Off 1967

MOISTURE ADJUSTMENT		FIT FACTOR		TOTAL ADJUSTMENT
1.04	X	0.79	=	0.82

MAXIMUM ADJUSTED PRECIPITATION DEPTH-DURATION VALUES (mm)

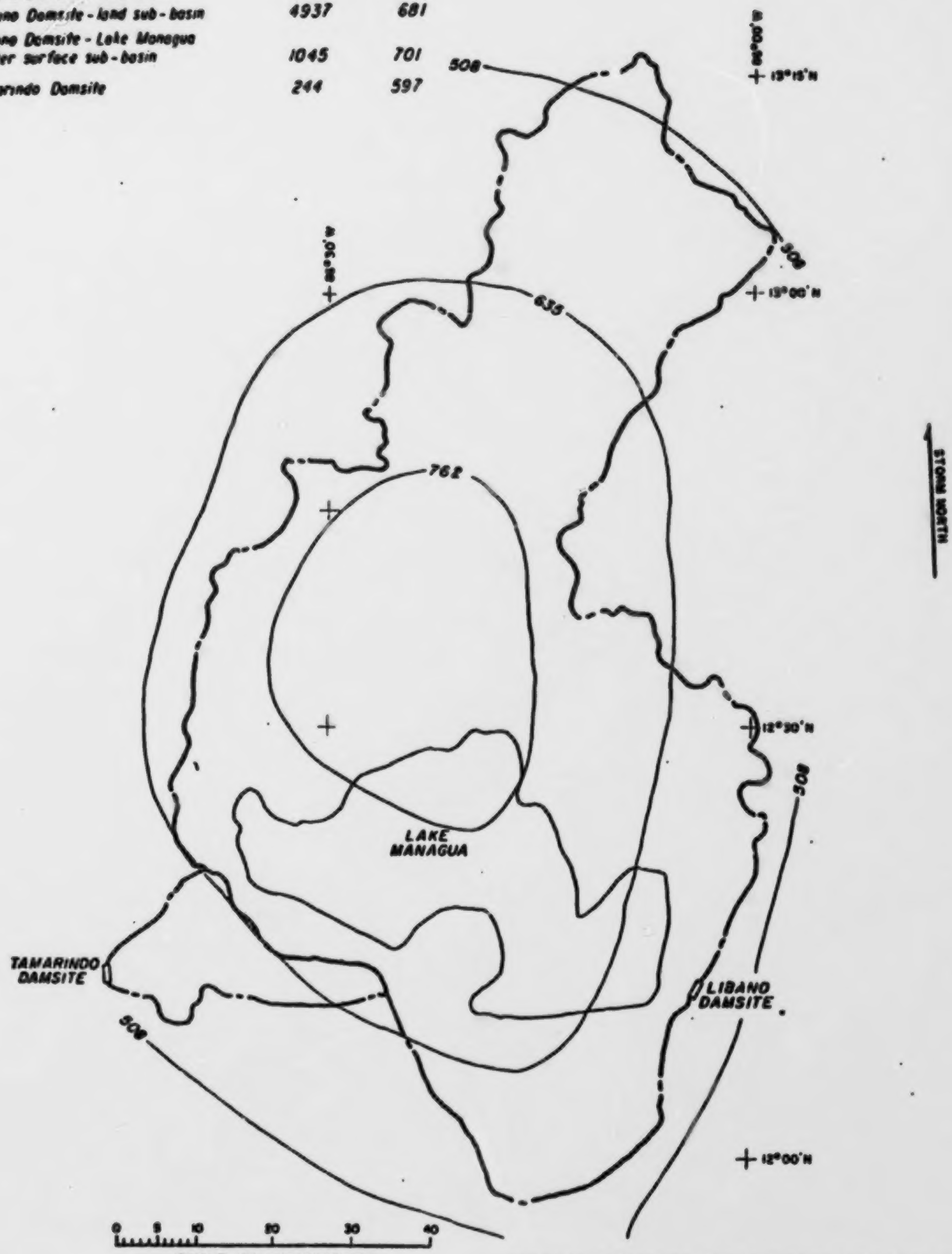
AREA (km²)	DURATION (HOURS)						
Libano damsite - Total area							
	6	12	18	24	30	36	48
5 982	223	312	390	410	423	429	433
Libano damsite - Land area only							
4 937	232	325	405	426	440	446	450
Libano damsite - Lake Managua surface area only							
1 045	183	256	320	336	347	352	355
Tamarindo damsite - Concurrent storm							
244	290	406	507	533	550	558	563

REMARKS as shown in plate 3 for the other areas (432, 340, and 544 mm, respectively) to that for the total area above Libano damsite (417 mm) to get the values in the top section above for the land and lake subbasins and Tamarindo damsite.

PREPARED BY C. E. Everson **DATE** 8 August 1977 **PLATE** 4

GPO 838-754

	Area (km²)	Average Precipitation (mm)
Libano Damsite - total basin	5982	683
Libano Damsite - land sub-basin	4937	681
Libano Damsite - Lake Managua water surface sub-basin	1045	701
Tamarindo Damsite	244	597


86°00'W
13°15'N
508
86°30'W
13°00'N
635
762
STORM NORTH
12°30'N
508
LAKE MANAGUA
TAMARINDO DAMSITE
LIBANO DAMSITE
508
12°00'N
0 5 10 20 30 40
SCALE OF KILOMETRES

TIPITAPA - TAMARINDO AND RIO BRITO PROJECTS — NICARAGUA
LIBANO AND TAMARINDO DAMSITES

ISOHYETAL PATTERN

STORM OF JUNE 27, - JULY 1, 1899
CENTERED NEAR HEARNE, TEXAS

PLATE 5

HDm-84 (6-78)
Bureau of Reclamation

SI METRIC

DISTRIBUTION AND ADJUSTMENT OF STORM PRECIPITATION

STORM NO. GM 3-4 **STORM DATE, LOCATION** 27 June-1 July 1899 at Hearne, Texas
TRANSPOSED (X **) INPLACE (** **) ABOVE** Libano & Tamarindo damsites, Nicaragua
DRAINAGE AREA (km²): TOTAL 5 982 **CONTRIBUTING**

MAXIMUM OBSERVED PRECIPITATION DEPTH-DURATION VALUES (mm)

AREA (km²)	DURATION (HOURS)											
Libano damsite - Total area												
	6	12	18	24	30	36	48	60	72	96		
5 982	127	241	358	480	511	572	615	686	704	716		
Libano damsite - Land area only												
4 937	127	240	357	479	509	570	613	684	702	714		
Libano damsite - Lake Managua surface area only												
1 045	130	247	367	493	524	587	631	704	722	735		
Tamarindo damsite - Concurrent storm												
244	111	211	313	420	447	500	538	600	615	626		

STORM DURATION (HOURS) 96 **ENDING TIME** 0700L 1 July 1899 **BASIN AVG PRECIP (mm)** 683

BASIS OF TIME DISTRIBUTION: Storm Studies - Pertinent Data Sheet, U.S. Corps of Engineers and Weather Bureau, 1947 for 5 982 km² (as shown in the top line above). These values were multiplied by the ratio of the average storm precipitation (Cont in Remarks)

COMPUTATION OF FIT FACTOR: 683 : 716 = 0.95

OBSERVED STORM DEWPOINTS

STATION	ELEVATION	DURATION	ENDING	OBSERVED	SEA LEVEL(SL)
200 km south of Hearne, Texas					23.9C

COMPUTATION OF MOISTURE ADJUSTMENT

OBSERVED STORM

MOISTURE SOURCE Gulf of Mexico
SL DEWPOINT 23.9 °C
INFLOW BARRIER 200 m
PRECIPITABLE WATER SL TO 12000m 73 mm
PRECIPITABLE WATER SL TO 200 **m** 4 mm
NET PRECIPITABLE WATER 69 mm

ADJUSTED STORM

MOISTURE SOURCE Western Caribbean
MAXIMUM SL DEWPOINT 27.8 °C
INFLOW BARRIER 1 000 m
PRECIPITABLE WATER SL TO 12000 m 103 mm
PRECIPITABLE WATER SL TO 1 000 **m** 24 mm
NET PRECIPITABLE WATER 79 mm

MOISTURE ADJUSTMENT = 79 ÷ 69 = 1.14

SOURCE OF MAXIMUM SL DEWPOINT Avg sea temp based on Pub 700 USN Oceanographic Off 1967

1.14 X 0.95 = 1.08
MOISTURE ADJUSTMENT **FIT FACTOR** **TOTAL ADJUSTMENT**

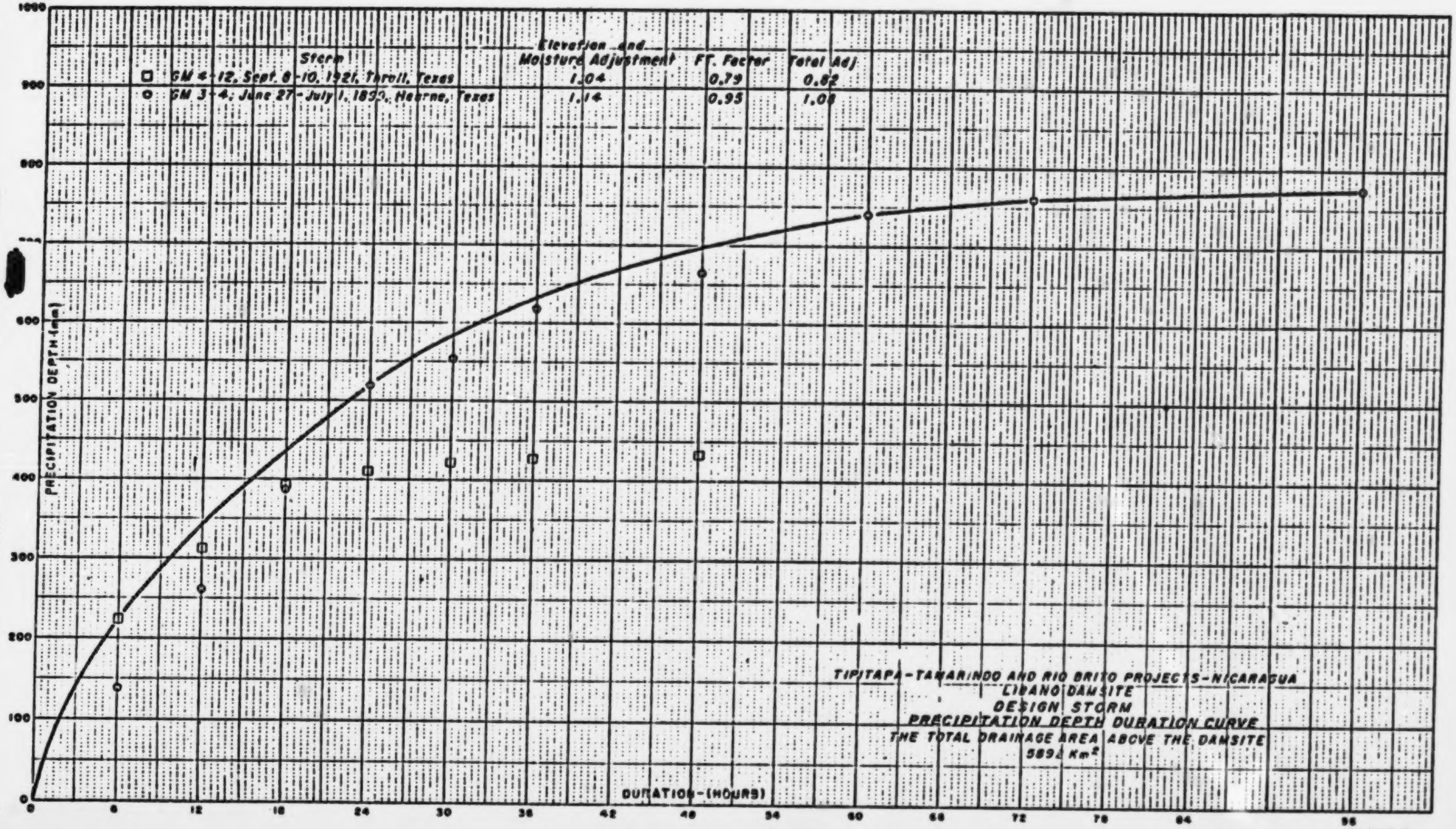
MAXIMUM ADJUSTED PRECIPITATION DEPTH-DURATION VALUES (mm)

AREA (km²)	DURATION (HOURS)											
Libano damsite - Total area												
	6	12	18	24	30	36	48	60	72	96		
5 982	137	260	387	518	552	618	664	740	760	773		
Libano damsite - Land area only												
4 937	137	259	386	517	550	616	662	739	758	771		
Libano damsite - Lake Managua surface area only												
1 045	140	267	396	532	566	634	681	760	780	794		
Tamarindo damsite - Concurrent storm												
244	120	228	338	454	483	540	581	648	664	676		

REMARKS as shown in plate 5 for the other areas (681, 701, and 597 mm, respectively) to that for the total area above Libano damsite (683 mm) to get the values in the top section above for the land and lake sub-basins and Tamarindo damsite.

PREPARED BY C. E. Everson **DATE** 8 August 1977 **PLATE** 6

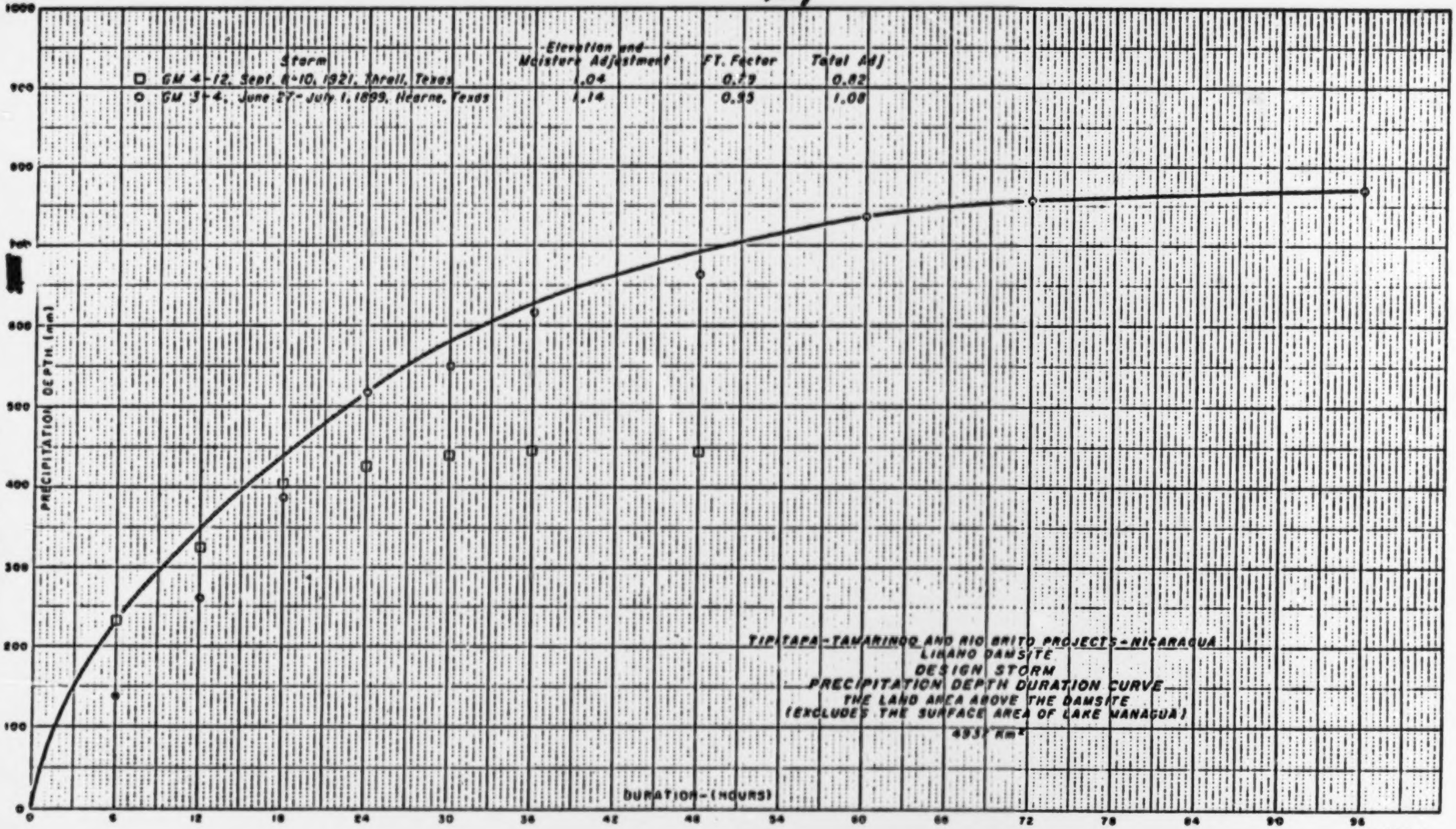
GPO 838-784



TIPITAPA-TAMARINDO AND RIO BRITO PROJECTS-NICARAGUA
LIBANO DAMSITE
DESIGN STORM
PRECIPITATION DEPTH DURATION CURVE
THE TOTAL DRAINAGE AREA ABOVE THE DAMSITE
5894 Km²

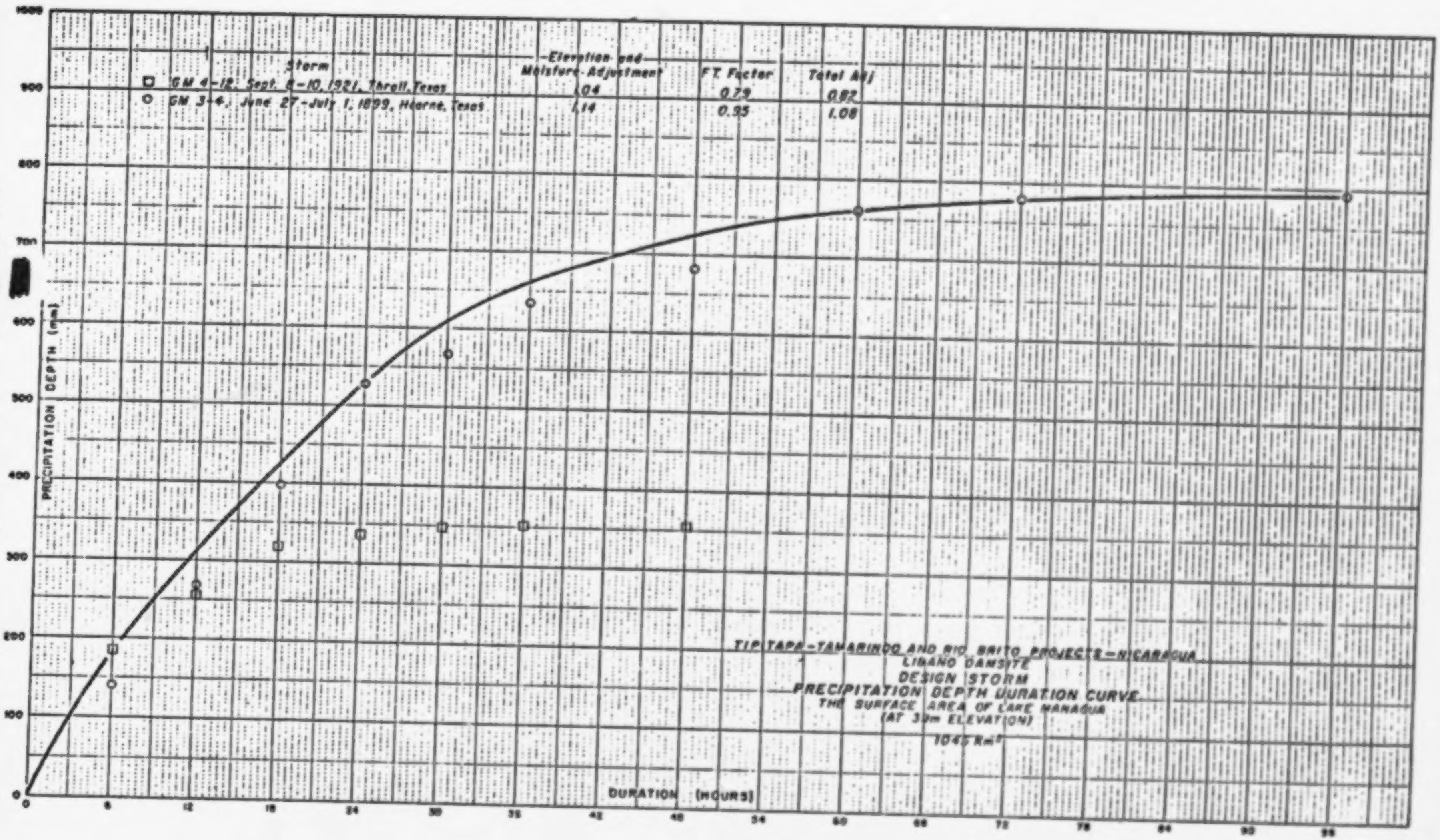
PLATE 7

103



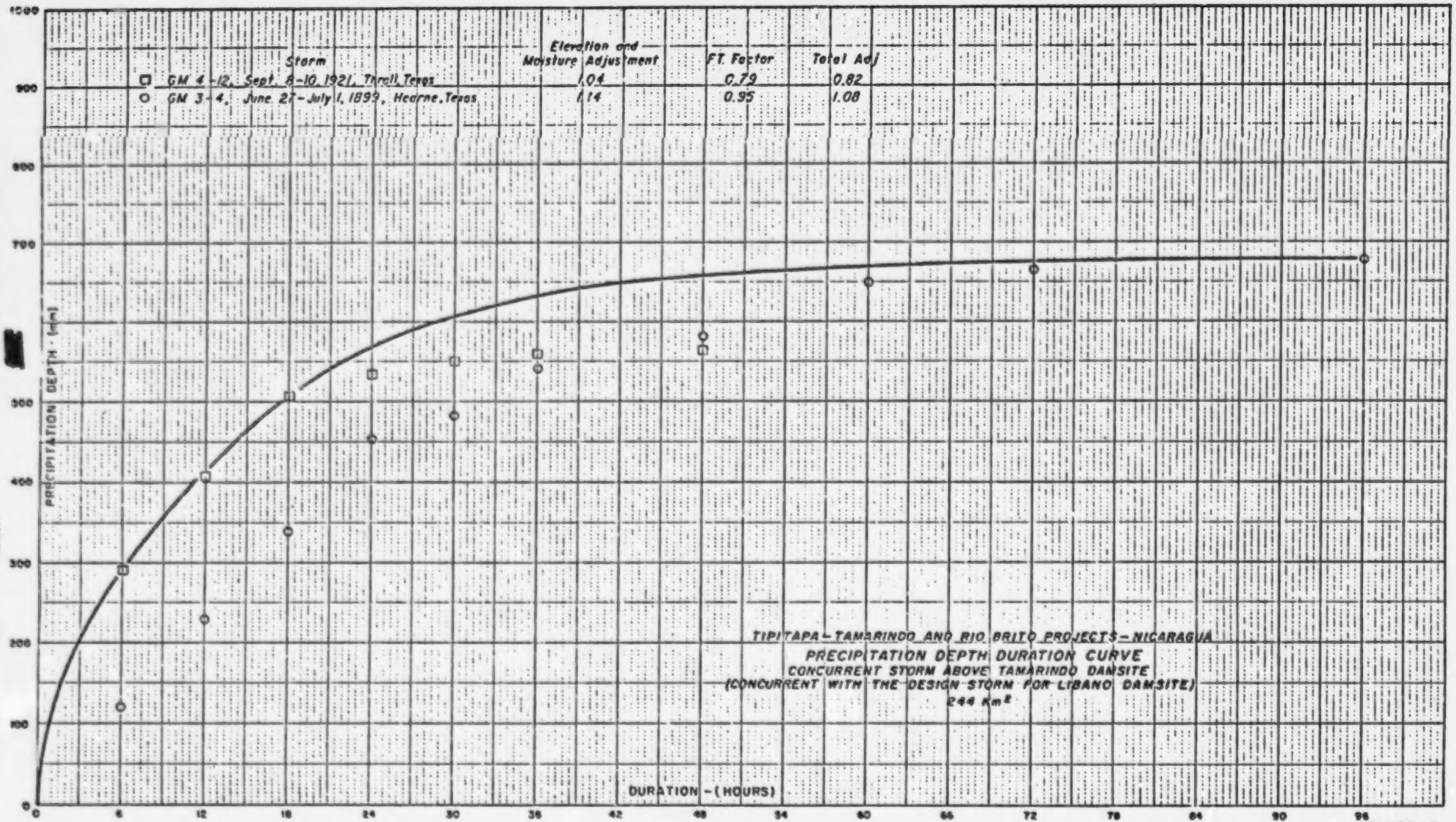
TIPITAPA-TAMARINDO AND RIO BRITO PROJECTS-NICARAGUA
LIHANO DAMSITE
DESIGN STORM
PRECIPITATION DEPTH DURATION CURVE
THE LAND AREA ABOVE THE DAMSITE
(EXCLUDES THE SURFACE AREA OF LAKE MANAGUA)
4937 km²

PLATE 8



TIPITAPA-TAMARINDO AND RIO BRITO PROJECTS—NICARAGUA
LIBANO DAMSITE
DESIGN STORM
PRECIPITATION DEPTH DURATION CURVE
THE SURFACE AREA OF LAKE MANAGUA
(AT 39m ELEVATION)
1045 Km²

PLATE 9



Storm	Elevation and Moisture Adjustment	FT. Factor	Total Adj
□ GM 4-12, Sept. 8-10, 1921, Thrall, Texas	1.04	0.79	0.82
○ GM 3-4, June 27-July 1, 1899, Hearne, Texas	1.14	0.95	1.08

TIPITAPA–TAMARINDO AND RIO BRITO PROJECTS–NICARAGUA

PRECIPITATION DEPTH DURATION CURVE
CONCURRENT STORM ABOVE TAMARINDO DAMSITE
(CONCURRENT WITH THE DESIGN STORM FOR LIBANO DAMSITE)
244 Km²

PLATE 10

HDm-34 (6-76)
Bureau of Reclamation
SI METRIC

DISTRIBUTION AND ADJUSTMENT OF STORM PRECIPITATION

STORM NO. ______ **STORM DATE, LOCATION** 24-31 October 1960 Northwest Coastal Region of Nicaragua **TRANSPOSED (** X **) INPLACE (** ___ **) ABOVE** Tamarindo & Miramar damsites, Nicaragua **DRAINAGE AREA (km²): TOTAL** 244 & 222 **CONTRIBUTING** ______

MAXIMUM OBSERVED PRECIPITATION DEPTH-DURATION VALUES (mm)

AREA (km²)	DURATION (~~HOURS~~) Days											
	1 day	2 days	3 days	4 days	5 days	6 days	7 days	8 days				
Tamarindo Damsite												
244	291	562	706	804	945	1 089	1 187	1 205				
Miramar Damsite												
222	Precipitation depth-duration values same as those above for Tamarindo damsite.											

STORM DURATION (~~HOURS~~) 8 days **ENDING TIME** 31 October 1960 **BASIN AVG PRECIP (mm)** 1 205

BASIS OF TIME DISTRIBUTION: Daily storm rainfall amounts for Ingenio San Antonio (12^0 31.3' N., 87^0 02.7' W., elevation 35 m).

COMPUTATION OF FIT FACTOR:

OBSERVED STORM DEWPOINTS

STATION	ELEVATION	DURATION	ENDING	OBSERVED	SEA LEVEL(SL)
Managua					23.3C

COMPUTATION OF MOISTURE ADJUSTMENT

OBSERVED STORM

MOISTURE SOURCE Pacific Ocean
SL DEWPOINT 23.3 °C
INFLOW BARRIER ______ m
PRECIPITABLE WATER SL TO 12000m 70.1 mm
PRECIPITABLE WATER SL TO ______ m ______ mm
NET PRECIPITABLE WATER 70.1 mm

ADJUSTED STORM

MOISTURE SOURCE Pacific Ocean
MAXIMUM SL DEWPOINT 27.8 °C
INFLOW BARRIER ______ m
PRECIPITABLE WATER SL TO 12000 m 103.6 mm
PRECIPITABLE WATER SL TO ______ m ______ mm
NET PRECIPITABLE WATER 103.6 mm

MOISTURE ADJUSTMENT = 70.1 ÷ 103.6 = 1.48

SOURCE OF MAXIMUM SL DEWPOINT Sea temperature charts in Special Publication 123, U.S. Naval Oceanographic Office, 1969.

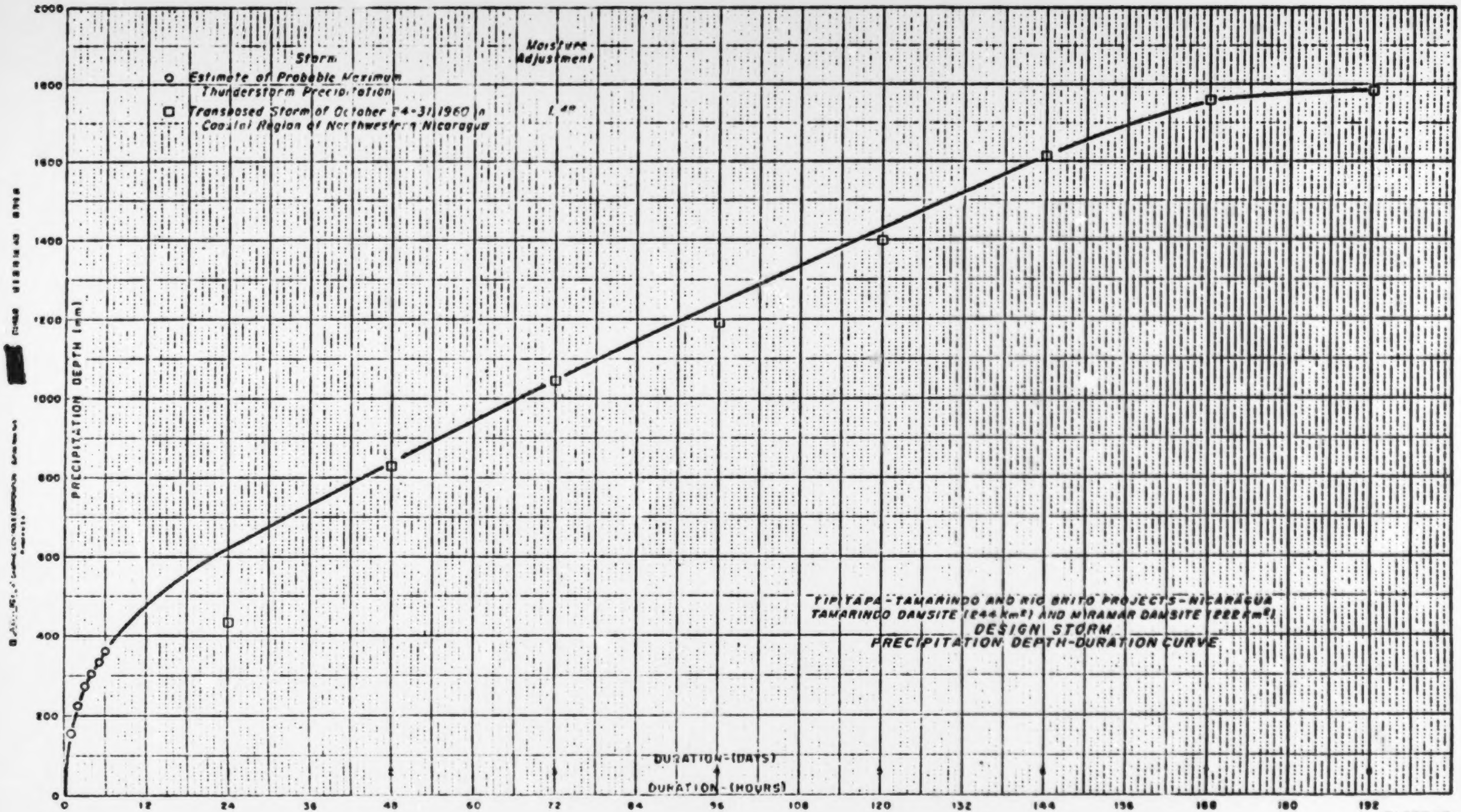
MOISTURE ADJUSTMENT ______ X **FIT FACTOR** ______ = **TOTAL ADJUSTMENT** ______

MAXIMUM ADJUSTED PRECIPITATION DEPTH-DURATION VALUES (mm)

AREA (km²)	DURATION (~~HOURS~~) Days											
	1 day	2 days	3 days	4 days	5 days	6 days	7 days	8 days				
Tamarindo Damsite												
244	431	832	1 045	1 190	1 399	1 612	1 757	1 783				
Miramar Damsite												
222	Precipitation depth-duration values same as those above for Tamarindo damsite.											

REMARKS The precipitation pattern in figure 47 of reference 2 was used in this study. The 1 200 mm isohyet enclosed an area of at least 800 km². The transposed value of 1 205 mm for basin average above Tamarindo damsite is believed conservative and appropriate without an area reduction.

PREPARED BY C. E. Everson **DATE** 18 August 1977 **PLATE** 11



TIPITAPA - TAMARINDO AND RIO BRITO PROJECTS - NICARAGUA
TAMARINDO DAMSITE (244 km^2) AND MIRAMAR DAMSITE (222 km^2)
DESIGN STORM
PRECIPITATION DEPTH-DURATION CURVE

PLATE 12

SURVEYS AND MAPPING NOTES

(December 1, 1976)

Introduction

The criteria for the surveys and mapping of the Tipitapa-Tamarindo Project were as follows:

1. The beginning points for all surveys will be located horizontally on the ground from scaled coordinates of identifiable features on the 1:50,000 maps made by the Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. Grid azimuths from these maps would be transferred to the ground by compass bearing adjusted to the proper magnetic declination.

2. Vertical control would come from existing Nicaraguan bench marks in the vicinity of the work. Vertical control for the topography of the damsites on the San Juan River would come from bench marks established by the San Juan Project.

3. There are three potential damsites on the San Juan River: San Isidro, Santa Cruz, and La Chorrera. Field engineering will choose the two best damsites and take topography of them.

4. On the Rivas-Brito part of the project a power canal survey for alinment and profile will be made for approximately 20 kilometers from

Lake Nicaragua to the end of the reservoir area where the canal enters the reservoir. Topography will be taken at two potential damsites, Brito and Miramar. The Brito damsite is adjacent to the Pacific Ocean and does not need surveys of the discharge channel. The Miramar damsite is approximately 6 kilometers from the coastline up the Brito River and requires alinement and profile surveys of a discharge channel.

5. The Tamarindo and Tipitapa portions of the project need only minimum surveys which will be determined later by the office. The Geographic Institute of Nicaragua is preparing topographic maps of this area.

Control Surveys

From the established criteria above, no triangulation was necessary for horizontal control. The accuracy required for the study did not warrant it. The primary purpose of the surveys was to obtain an alinement and profile of the power canal and topography of the damsites so that earthwork estimates and designs can be made. The 1:50,000 maps gave sufficent horizontal control. The beginnings and endings of the surveys were referenced by scaled coordinates of easily recognized features from map to terrain.

Vertical control for the Rivas-Brito area was taken from two existing bench marks, D-72 and E-5. Vertical control for San Isidro damsite and La Chorrera damsite was taken from bench marks 10 and 24, established by the San Juan Project.

Site Surveys

The topography for the San Isidro damsite was surveyed using a plane table and alidade.

The topography for the La Chorrera damsite was surveyed using the transit-stadia method.

The topography for the Brito damsite was surveyed with a grid configuration using transit, tape, and stadia.

The topography for the Miramar damsite was surveyed in the same manner as the Brito damsite.

Canal Surveys

The canal surveys commenced at the mouth of the Las Lajas River on its south bank. The route of the canal follows the old Corps of Engineers barge-canal route to the end of the reservoir near Rio Grande.

The alinement of the canal was measured by transit and tape. The profile elevations were obtained by differential leveling. The distances between P.I.'s were checked with stadia.

DECEMBER 16, 1976 MEMORANDUM

To: W. V. Halliday, Project Engineer

From: K. R. Kiel, Geologic Advisor

Subject: Surface Geologic Investigations of Tipitapa-Tamarindo and Rivas-Brito Areas

The attached reports covering the subject areas were prepared to assist you and the project geologist, Mr. Pablo Martinez, to make up a final drilling program so that prefeasibility layouts and designs of structures can be accomplished. Reference should be made to the report "Preliminary Evaluation of Active Faulting in Western Nicaragua," by Woodward-Lundgren & Associates, undated (probably prepared in 1975), and the 1:50,000-scale geologic maps prepared by Catastro e Inventario de Recursos Naturales.

Rivas Project

Introduction

The Rivas Project will divert water from Lake Nicaragua to the Pacific Ocean, utilizing a power drop of approximately 30 meters. The principal features of the project are a 17-km-long canal through the continental divide, a dam on the Brito River holding a reservoir to the elevation of Lake Nicaragua (±31 m), and a sea level channel from the dam to the Pacific Ocean.

The canal from Lake Nicaragua will follow up the valleys of the Rio Las Lajas and Rio Guiscoyal to a point near La Trocha (1256.7 N., 628.0 E.) and cut through the continental divide (with maximum depth of about 20 m) to follow the valley of the Rio Grande to the reservoir. The dam on the Rio Brito will retain a reservoir in the valley of the Brito and its tributaries, Rio Grande and Tio Tola. The channel to the Pacific will follow the Brito Valley.

General Geology

The Rivas Project spans two geologic provinces, the Rivas Plains and the Brito Ridges. In the project area, each province, except for recent alluvium, consists of a single formation and its residual soil.

The Rivas Formation, of late Cretaceous age, is a thick section of marine sediments consisting mainly of tuffaceous shale, siltstone, and sandstone.

In the project area, observed bedding varies from one-half inch to more than 3 feet thick. The Rivas Formation is described as intruded by numerous dikes and sills; however, the only igneous rock observed in the project area is the Lomas Las Mesas sill, adjacent to the canal line on its right side near km 15. The entire length of the canal will be cut in the Rivas Formation.

The Brito Formation, of early Tertiary age, overlies the Rivas Formation with probable erosional unconformity. It is similar to the Rivas in composition but contains several prominent limestone units and its clastic sediments are notably more calcareous than those of the Rivas. As observed in the project area, the Brito contains fewer thick beds than the Rivas. This distinction, however, could be more apparent than real. The steeper topography of the Brito area, a few road cuts to about 25-feet high, and the cliffs at Punta Brito expose thick sections of the Brito, whereas I have observed the Rivas only in low outcrops, mostly in streambeds, where the thicker, more resistant beds would be prominent.

The lower damsite on the Rio Brito (hereafter called the Santa Adela damsite) lies within the Brito Formation. The upper damsite (hereafter called the Miramar damsite) may lie entirely within the Brito Formation or may (as indicated by the CATASTRO geologic map) span the contact between the Rivas (left abutment) and Brito (right abutment) formations.

Seismicity

The Rivas area appears to be one of the more stable areas of western Nicaragua. The Woodward-Lundgren map of earthquake epicenters indicates only a few low intensity earthquakes recorded near the project area. No earthquake damage was noted in observing the condition of a very old church in Rivas, and no evidence of fault activity was noted in the field. However, the contact between the Rivas and Brito Formations is believed to be a fault contact, and an area a few kilometers to the southeast of the project area (Woodward-Lundgren's lineament No. 9) is interpreted with "a high level of confidence" as an active fault. A northwestward extension of this lineament would cross the area of the Rio Brito damsites.

Rivas Cut (Canal)

The inlet of the cut on Lake Nicaragua is at the mounth of Rio Las Lajas. A highway bridge will cross the cut near the inlet.

The lake sediments of the mouth or river consist of fine to medium sand with a little small gravel. A drill hole will be needed here to determine depth to rock. Firm, shaley sandstone outcrops along the lakeshore about 200 meters north of the river mouth. If the sediments of the river mouth prove deeper than is desirable, consideration should be given to straightening the alinement to place the inlet structures, and possibly the bridge piers, on firm rock.

Following the left bank upstream, the beach sand at the river mouth (km 0+000) changes at about km 0+250 to a residual clay soil, and at km 0+350 ± rock outcrops in a gully. Following the line through to about km 6+500, occasional rock outcrops were noted in the riverbed and in gullies. The soil in this area is mostly heavy clay and appears to be about 1 to 3 m thick. From km 6+500 ± to about km 9+800 the line follows flat terrain that shows no outcrops. The few gullies encountered indicate that maximum soil depth is at least 3 m. From km 9+800 to about km 12+000 frequent outcrops in gullies and streambeds were noted.

Soil depth appears to average 1 to 2 m. From km 12+000 to km 16+700, the terrain is extremely rough and appears to have been cut in an old valley fill. Soil depth appears to vary from 1 m to as much as 10 m. Frequent outcrops are found in the streambed and in deep gullies. In a few places, the streambanks show as much as 6 m ± depth of rock outcrop. These larger outcrops show a much larger proportion of thin-bedded rock than do the smaller, scattered outcrops. The line was not walked beyond km 16+700.

The soil observed along the alinement is mostly clay that will be stable on slopes of 1.5:1 if protected from erosion by suitable vegetation. From km 12+000 to km 16+700 some of the deeper soil sections contain silty to sandy layers and may require somewhat flatter slopes.

The excavation characteristic of the rock must be determined by drilling. All outcrops observed are weathered to some extent. The thin-bedded rock will rip where moderately weathered and may prove ripable in lightly weathered to fresh condition. The thicker beds will not rip except where considerably weathered. Slopes of 3/4:1 to 1/2:1 appear feasible in moderately weathered rock, and fresh to lighly weathered rock will be stable at 1/4:1 unless very adverse jointing is encountered. The low dips, usually to the southwest, do not appear to present any dip-slope problems.

Recommendations

1. The type sections of the Rivas and Brito Formations should be reviewed in the field as a basis for estimating construction characteristics.

2. Drilling. - Drilling should establish:

   a. Foundations for structures. - Depth of sediments at the mouth of Rio Las Lajas should be established. If the foundation here proves unsatisfactory, it appears that good foundation for structures here can be found north of the river mouth.

   b. Ground-water regimen and permeability of the rock in the cut. - I do not expect much action here. Springs in the area are notable by their absence. Any loss or gain of water in drill holes should be documented as closely as possible. Morning water levels are required and gravity water tests should be taken through the depth of the cut that will be below water surface.

c. Excavation characteristics of the cut. - Depth and character of overburden, depth of weathering, bedding characteristics, hardness, etc. Any raveling or caving in the drill holes should be strictly documented. Casings should be set through each zone of raveling as soon as it is defined and before continuing drilling.

Drilling Program

Drilling at the inlet, except for the hole scheduled to test the depth of sediment, will be controlled by location and type of structures. Foundation holes should penetrate 10 feet to 20 feet of firm rock.

The scheduled holes at km 4 and km 10 appear satisfactory. An additional hole between km 7 and km 8 (easily accessible in dry weather) would be desirable. In the Rio Grande drainage a hole should be drilled near PI No. 91 to test whether the hard igneous rock of the Lomas Las Mesas sill will be involved in the cut, and two other holes should be located in the field to test the maximum depth and character of overburden. Holes should be drilled 10 or more feet below canal grade.

Rio Brito Damsites

The suitability of either damsite appears to depend mainly on the depth of its channel fill. Abutments appear sound at both sites. The more desirable damsite should be the first investigation of the project.

Santa Adela Damsite

The Santa Adela damsite will span a channel fill nearly 2 km wide and will base both abutments on the calcareous marine shales and sandstones of the Brito Formation. The beds here strike about N60E (approximately parallel to the dam axis) and dip 15-25° southwest (downstream).

Under thin soil cover the surface rock is strongly weathered and loose to a depth of 2M to 4M, showing some soil creep. Below these depths the rock appears to be tight and weathering to decrease rapidly. The surface of the valley floor at the damsite is clayey sand, wet to the surface. The banks of the river channel show a few layers of cleaner sand, held together with a root system that lets it form vertical banks.

Drilling Recommendations

There cannot be too many drill holes in a damsite. A minimum of 5 on the dam axis are recommended for proof of Santa Adela at this stage of investigation, unless fewer holes prove it unsuitable. Hole 1 should be at the middle of the valley fill. If hole 1 proves satisfactory, holes 2 and 3 should split the distance to the abutments on either side of 1. Additional distance-splitting holes should be drilled if time and money permit. These holes should be drilled at least 20 feet into sound rock.

At least one hole should be drilled in each abutment at top-of-dam elevation. These holes should be drilled at least 50 feet into sound rock and preferably should be drilled to the elevation established by the valley holes as the base of the dam.

In all damsite holes water testing is critical. Loose rock should be gravity tested to at least 50 gal/min. Sound rock should be pressure tested to at least 1.5 times proposed reservoir head.

Miramar Damsite

The right abutment and the valley floor (except for its lesser width) appear very similar to those of the Santa Adela site. The valley floor, however, is dry at the surface and is partly in farmland. The left abutment is based on an L-shaped spur ridge. This ridge, seen in the field, does not appear to have the solid bulk indicated on the map. The free leg of the L, extending downstream, is thin and is probably deeply weathered.

The dam axis (as presently surveyed) is based on the downstream leg of the L near its tip. The axis on the left abutment should be moved upstream to meet "cross-valley" leg of the L, which has much more mass.

There is a saddle in the cross-valley leg of the L but its bulk appears adequate.

The CATASTRO geologic map shows the right abutment as Brito Formation, the left as Rivas. This infers a fault (not necessarily active) through the damsite. Outcrops are very few and small on the left abutment, but neither Pablo Martinez or I found any notable difference in the rock of the right and left abutments (our inspection was, necessarily, brief).

Drilling

The drilling program for Miramar should follow the outline made for Santa Adela. In addition, a hole should be drilled in the saddle in the cross-valley leg of the left abutment ridge to determine its leakage potential and/or its suitability for any structure that might be placed there.

Construction Materials

Adequate supplies of impervious fill appear to be available from the farmlands around Miramar and El Capulin and should be present in the large alluvial area above Miramar damsite. Random fill will be available from the ridges in either the Brito or Rivas Formations and it will be possible to sort an undetermined amount of riprap from this material. Additional supplies of riprap can be had from the Lomas Las Mesas sill, about 4 km from Miramar damsite and 8 km from Santa Adela. At the beach, on the southeast side of the Brito valley, a massive coquina limestone is exposed. Its extent and properties as construction material should be further investigated.

No suitable supplies of sand and gravel have been noted in the area. The beach at rivermouth is uniform fine to medium sand with a trace of small gravel. A small patch of dirty cobble gravel was noted near the beach at the right side of the valley but appears to be a local deposit from a side drainage. Recoverable deposits may be found in the valley fill during damsite drilling. A well near the beach at the right side of the valley is about 10 feet deep; the water, sweet and clear. Viewed from the top by reflected sunlight, the bottom of the well appears to be a fairly well graded sand with small gravel.

TIPITAPA-TAMARINDO PROJECT

Introduction

The Tipitapa-Tamarindo Project would divert water from Lake Nicaragua to the Pacific Ocean via Lake Managua, utilizing a pump lift of about 8 m from Lake Nicaragua to Lake Managua and a power drop of about 39 m from Lake Managua to the Estero Real, the Pacific estuary of Rio Tamerindo.

The Tipitapa unit of the project includes an inlet channel from Lake Nicaragua to a dam and pumping plant on Rio Tipitapa that will lift water to the level of Lake Managua and channel improvement from this reservoir to Lake Managua.

The principal feature of the Tamarindo unit is the 8 km long Ceiba-Mocha cut that will carry water through the continental divide at the level of Lake Managua (±39 m). Maximum depth of cut will be about 30 m. On the Pacific side of the cut alternate plans would (1) take the water through a 12-km-long canal continuous with the Ceiba-Mocha cut to a powerplant near the head of the Estero Real or (2) create a reservoir to the level of Lake Managua in the basin of Rio Tamarindo. This would require a dam on Rio Tamarindo and a 6-km long dike between the Rio Tamarindo and Rio Izapa drainage basins, and a sea level channel to the dam.

General Geology

The project, from Lake Nicaragua to the head of the Estero Real, spans three geologic provinces - the Tipitapa Plains, the Nagrandan Plains, and the Tamarindo Mesas.

The Tipitapa unit lies entirely within the Tipitapa Plain, an erosional surface developed on the massive to thick-bedded agglomerotic tuffs of the Plio-Pleistocene age Las Sierras Group (hereafter called "the tuff"), and an uncomformably overlying group of thin- to medium-bedded, unconsolidated to moderately consolidated pyroclastics, sediments and old soil surfaces (hereafter called unit b).

The Ceiba-Mocha cut lies in the Nagrandan Plains province. The bulk of the cut will be in the Las Sierras Tuff. The tuff is here thinly overlain by patches of later deposits similar to unit B.

At the western edge of the Nagrandan Plain, near km 11 of the Ceiba-Mocha cut-canal line, the Miocene age Tamarindo Formation., a series of acid lava flows, tuffs, and ignimbrites, emerges from beneath the Las Sierras. In general, this rock is hard, tough, and durable, its surface characterized by massive joint blocks. In a few places it shows as only moderately hard and closely jointed.

Near the head of the Estero Real the Tamarindo Formation. intertongues with the El Fraile Formation., a mariene series of waterlaid tuffs and agglomerates and tuffaceous, calcareous sandstone and siltstone.

Las Sierras Tuff

The Las Sierras Tuff is a body of massive to thick-bedded agglomeratic tuff that is exposed over wide areas within a 50-km radius of Managua. Its composition, bedding, structure, hardness, erosion resistance, and other properties vary considerably from place to place, both vertically and horizontally. It produces nearly all of the hand-cut and saw-cut building blocks used in western Nicaragua. It is used in the construction of walks, walls, buildings, dams, canal linings, bridge piers, and almost any other structure known to man.

It will be the major excavation unit in the Ceiba-Mocha cut and the Tipitapa outflow channel, will probably provide a foundation for Tipitapa Dam, and should be considered as a construction material at both units of the project.

At the sawed-block quarry near Jinotepe, where it is produced in blocks of three thicknesses (all the same price at about $8 per m ^{2}) it has no visible structure and cannot be ripped. At the Tipitapa bridge it shows no structure except a few joints and bears ripper scars (left, I am told, by a D8 Caterpillar tractor) to 6 inches deep, but it is apparent that very little rock was disturbed by this method.

Along the new Leon Highway in the area of the Ceiba-Mocha cut, it has been ripped and trimmed to very smooth 1/4 to 1/1:1 slopes. Some of these show horizontal lenses that have ravelled to depths of several feet. Along the western edge of Lake Managua the tuff is bedded and gently folded. It is generally hard, but in the vicinity of the cut intake it is as soft as many soils, but still shows fair erosion resistance and does not disintegrate in water. Along the line of the cut some exposures look rippable, others not.

The properties of the tuff, at least its rippability, must be determined for each construction locality. Velocity checks should be made on representative exposures in each area. If these leave any doubt, actual ripping tests should be conducted.

As a construction material its hardness, shear strength, and resistance to erosion and vibration should be laboratory tested with representative samples from each locality.

Seismicity

A north-south trending fault runs through the town of Tipitapa. Its traces can be found in the riverbed from about 50 m west of the present highway to several hundred meters below the old highway bridge.

Woodward-Lundgren extend the width of the fault zone several km westward into Lake Managua and interpret it with a "high level of confidence" as an active fault. The epicenters of several earthquakes of moderate intensity are mapped along this fault. The epicenters of a few low intensity quakes are mapped in the Laguna de Tisma area.

The Mateare Fault passes through Lake Managua just east of the inlet of the Ceibo-Mocha cut. Woodward-Lundgren classify it as active with an apparent low level of confidence.

The epicenters of two low intensity earthquakes are mapped in the area of Puerto Somoza.

Tipitapa Unit

The tuff and unit B compose the geologic setting for the Tipitapa Unit. Intermittent outcrops of the tuff occur on both sides of the river from the highway at Tipitapa (the one in present use) to Hato Grande. It also outcrops over broad, flat areas in a triangle roughly bounded by Panaloya, La Ceibita, and Santa Julia and is reported (by the driller on drill hole 1, who has worked here before) to underlie much of the surrounding area at shallow depth. The harder beds of unit B form intermittent outcrops along the parts of the river not occupied by the tuff (I am not yet sure how much that is) and form broad, flat outcrops on the flatlands above the river.

It appears that unit B was deposited on a roughly-eroded surface of the tuff and probably contains, within unit B, several old surfaces of weathering and erosion.

The tuff, as observed in the Tipitapa area, shows no bedding and few joints. It will stand in vertical cuts and provide firm foundation for earth or concrete dams (see "Las Sierras Tuff" section).

Unit B can be easily ripped or excavated with stiff arm shovels or with cutter or bucket dredge. It would probably excavate well with draglines. Unit B is quite variable in composition, but in general will stand on 1/2:1 slopes above water. Underwater some units will erode somewhat and there may be a few beds that would slump; 1-1/2:1 slopes would be secure; 1:1 would probably be okay.

Inlet Channel

All drilling to date (drill holes 1, 2, 3, 4, and 9) indicates that the channel can be dug from Lake Nicaragua to Hato Grande with nearly all excavation in unit B. The cut would start in Lake Nicaragua sediments (mostly sand) but would (as now laid out) probably enter unit B within the first km and remain principally in unit B to Hato Grande. From Hato Grande to the plywood mill the tuff outcrops on the right riverbank, but this can probably be avoided to a great extent, as most, perhaps all, of the exposures on the left bank are of unit B. The tuff is exposed in the left bank at the plywood mill and upstream through Pasquier and shows in patches around the left bank area to Tipitapa; however, drill hole 9, on the right bank across from Plywood found unit B to 50-foot depth, and the general lay of the land suggests unit B in the right bank to El Quemado. Three drill holes are scheduled to test this area.

Recommendations

Excavation schedule should be set up considering the great bulk of the material to be unit B; however, provision should be made to excavate tuff if and when it is encountered.

A seat-of-the-pants guess says that the best route for the channel would swing the alinement through Laguna de Tismo to place the Lake Nicaragua-Laguna de Tismo leg in the low ground about 1.5 km west of the present line.

The final best route for the channel could be determined by geophysical survey.

Damsite

It appears improbable that a good damsite will be found below El Rio and quite probable that none will be found below El Quemado. The three drill holes laid out in this area should indicate whether the search should start at El Rio or at El Quemado. One or more potential damsites should be chosen in the field by a geologist and approved for further investigation by an engineer before more drill holes are laid out.

The triangular area bounded by Pasquier, Club Nautico, and El Quemado should be very carefully checked if any structure other than the channel is to be placed there. The El Quemado-Club Nautico reach of river may be fault-controlled, and one or more buried channels may cross the bend.

I believe it quite possible, if necessary, to base one end of the dam on unit B. In general, the unit appears to be tight and to have the bearing capacity to support an earth dam of the height required. There is enough variation within the unit that any chosen area would have to be evaluated on its own merits. Care would have to be taken to identify any incompetent and/or leaky beds that might be present. I believe that with good drilling equipment (including crews) that very nearly 100 percent core recovery can be had in this material.

Outflow Channel

Most of the outflow channel improvement will be excavated in the tuff. From the fault line about 50 m east of the present highway to Lake Managua surface conformation and drill holes 5 and 6 indicate that excavation will be in muddy to clean, skip graded, basaltic sand, and pea gravel. This material could be washed as it is excavated and stockpiled as a materials resource.

Construction Materials

As just noted, large quantities of basaltic sand are available at the source of the Tipitapa on Lake Managua. This is a fair grade of cement sand when washed and appears to be the best available. No source of gravel has been located.

Impervious fill will almost certainly be found in adequate quantities in the farmlands near the damsite (wherever that is). Spot checks of the topsoil turned up many good hand tests. Much of the soil in the area is thin (1 meter or less) and much of it is too lean; however, the leaner soil probably also indicates the thinner spots in most cases. The best implement for this exploration would be a power auger (preferably bucket) but in most places a hand auger will do. Sources might also be developed within unit B. It contains many beds of semiconsolidated clay and clayey sand.

Basaltic rock about 25 km northeast of Tipitapa appears to be the nearest hardrock source.

The Las Sierras Tuff should not be ignored as a construction material. Tuff of much lower quality than that of the Tipitapa has been used as the main construction material in many structures (including dams) in western Nicaragua.

Sawed blocks from the Tipitapa area would provide an adequate facing for the dam, and could cheaply replace concrete in many structures. Sheared, shot, or ripped, it will provide acceptable random fill. It will probably provide a rather poor grade of riprap.

TAMARINDO UNIT

Ceiba-Mocha Cut

The bulk of the cut will be in the massive to thick-bedded agglomeratic tuffs of the Las Sierras group (hereafter called "The Tuff"). The tuff outcrops along the lakeshore at the cut inlet and for several km to the south, and is exposed in nearly all of the higher ridges in the cut area. The tuff along the lakeshore shows occasional gentle folds striking east to northeast; most ridges in the cut area trend in this direction. As exposed along the lakeshore to a point about 1 km south of the inlet the tuff is quite hard, its rippability doubtful. Near the cut inlet a softer unit underlaying the hard tuff is exposed on the lakeshore and the harder tuff forms a scarp about 5 meters high near the shore. As exposed in the ridges, much of the tuff has been ripped in road cuts, but in a few places appears too hard and massive to rip. The tuff is overlain in much of the area by thin-bedded pyroclastics and clayey to sandy soil. These overlying units appear to be quite thin in most places.

The tuff will stand, generally, on 1/4:1 slopes, but lenses (probably thin and few) will be encountered that will require either benching or local dental work to maintain this slope. I believe a net slope of 1/2:1 or a slope of 1/4:1 with dental work can safely be proposed for the tuff above waterline. The overlying beds will probably require 1/2 to 3/4:1 and the soil 1-1/2:1 slopes for a stable cut.

The soft lower unit exposed at the inlet, and similar beds or lenses will require protection from erosion in the canal proper. Canal slopes of about 3/4:1 could be protected, where necessary, with a lining of tuff slabs sawed from the harder units in the cut.

Ground-water levels should be watched carefully in drill holes along the canal. There is a deep aquifer with a strong artesian head under much of this area (a well at San Gabriel hit it at 180 feet and water level rose to 12 feet). I believe that it is too deep to be involved in the cut, but it could be high in places.

Holes along the cut should be kept open where possible, and water levels periodically checked.

Canal

To about km 11 canal excavation appears quite similar to the Ceiba-Mocha cut and embankment material will be available from adjoining farmlands. A drill hole between km 10 and km 11, however, would check for possible Tamarindo Formation close to the surface.

From km 11 to its end, the canal line is on, or just skirting the Tamarindo Formation. To about km 16 there are many draws and gullies containing patches of alluvium, soil, and pyroclastics, however, the principal geologic features are Tamarindo Rock, which is hard to excavate and Tamarindo soil which is thin, lean, and rocky. Random embankment material might possibly be ripped from the softer units of the Tamarindo, but impervious material would have to be hauled from the area north of km 11 or from the flats southeast of El Tamarindo (if the material there is okay, as I believe it to be from a few samples near town).

Detailed mapping of the canal route on the new topography and precise definition of materials sources are needed to define feasibility of canal construction and to locate any drilling that may be necessary.

Also, a powerplant site at the end (as mapped) may be difficult (see Dam section).

Tamarindo Dam

About 300 meters downstream from the highway bridge a rib of very massive rock crosses the Rio Tamarindo. I believe that this is the last damsite on the stream that can be based on Tamarindo Formation. Just downstream the river drops into a long pool of deep, quiet water. I believe this pool was formed by the river eroding, in "falls" fashion, a layer of El Fraile Formation (which intertongues with the Tamarindo Foramtion) and block-caving the overlying tongue of Tamarindo. This condition may also exist under the left streambank. Tamarindo Formation continues in the right bank well into the town of Tamarindo, where the El Fraile appears to replace it in the right bank also. Drill holes A, B, and C (marked on the geologic map) will test this theory. If I am correct, any damsite below this one will have to be developed, at least in part, on the El Fraile Formation, and may well have a deep channel filled with huge boulders of Tamarindo rock to contend with.

Drill hole A should be placed on the outcrop Pablo and I called El Fraile Formation; B near the stream beside the long pool (it is looking for a batch of boulders); C on the damsite abutment if this site is chosen (looking for a possible tongue of El Fraile below the Tamarindo rock-in-place).

Materials

I believe that gravel and sand can be dredged from the Estero Real near and just below the town of Tamarindo. The stream fill, as it enters the Estero Real, is beginning to grade out from boulders and cobbles to gravel and sand and should become gradually smaller sized with distance down the estuary. Most of this material is derived from the Tamarindo Formation, which contains a considerable amount of acidic glass. Its reaction with cement should be determined.

A very limited check suggests that good impervious fill material may be had from the flats south of Tamarindo.

Tamarindo Dike

The dike, about 6 km long, begins (north to south) in thin-bedded pyroclastics interbedded with old soils that overlie (probably quite thinly) the Las Sierras tuff. In about 2 km these beds thin out to reveal patches of tuff. About 2 km farther south the tuff gives way to the typical Tamarindo soil.

It thus appears probable that the first 2 km will rest on recent beds (these will provide an adequate formation), the middle two on the tuff, and the last two on Tamarindo. Soil materials will be plentiful at the north end and will probably be available with 1-2 km through the length of the dike. Hard rock will be available only at the south end.

For this stage, one drill hole in the Tamarindo ridge at the south end of the dike to test its leakage potential appears to be adequate for drilling.

Borrow areas should be roughly defined.

Note: In all drill holes in the Tamarindo Formation, special attention should be given to water losses and each 10 feet of sound rock should be water tested. No indication of other than surface looseness has been noted, but this will be the principal "rim rock" of either reservoir or the canal.

NOTES ON SEISMOLOGY AND DESIGN EARTHQUAKES

A rather comprehensive study of the regional tectonics and seismic history of Nicaragua was conducted in 1976 during the prefeasibility study of the Rio San Juan Hydroelectric and Navigation Project. This study included the area which provides a setting for the Tipitapa-Tamarindo Hydroelectric Project, including a few specific sites. The above-mentioned comprehensive study can be found as Chapter III - Seismology of Appendix B - Geology, Seismology, and Construction Materials included in Volume 2 of the Prefeasibility Report of the Rio San Juan River dated December 1977.

The study is not repeated in this report although certain results pertaining to the Tipitapa-Tamarindo Project are summarized below.

Table B-6 summarizes the relationship between each project damsite and the design earthquakes from each tectonic province or feature. The design earthquakes shown were used in the response spectrum analyses for the damsites. The results of these analyses are shown in table B-7. The computations of the analyses are in project files.

Results and Conclusions

The results of the computation for maximum ground acceleration and the response spectrum analyses based upon assumed design earthquakes are summarized in table B-7. The values of absolute acceleration shown were based upon 5 percent damping which is reasonable for an average gravity-type structure. The computations were based on assumed rock motions; the effects of overburden were not included. Future studies upon the effects of overburden at each site should be done prior to any specific structural designs at the sites. It should also be noted that the resonse spectrum analyses were based on a single-degree-of-freedom system so, for structures behaving elastically, the response of multidegree-of-freedom structures should be estimated by superposition. Time-history analysis using accelerograms whose response spectra resemble the design spectra may be necessary for final design, depending upon the structure to be used.

All potential damsites on the Rio San Juan (inlcuding San Isidro) were critically affected by the C event, the near surface events of the Nicaraguan Depression, referenced to no known fault. It is obvious that these events are highly theoretical and finding actual faults in the damsite areas will have a profound effect on the dam features. Prefeasibility geologic exploration is not adequate to locate any such faults, especially since so little can be seen by surface study. The areas of rapids on the river could be fault areas which would modify the studies at San Isidro. Therefore, great caution should be used if further studies or actual construction in this area is proposed These sites could also be critically affected by the effects of overburden due to the deep weathering to the deep weathering of materials in the area, and potential liquefaction of the deep streambed sediments which are mainly poorly graded, fine sands and silts. it is imperative that the seismic net be expanded to thoroughly cover the San Juan Channel area prior to any further study.

The Panaloya damsite (later replaced by El Libano Pumping Plant Site) was critically affected by the C event, referenced directly to the Tipitapa Fault. Therefore, the earthquake accelerations this structure would be subjected to depend directly upon its location relative to the Tipitapa Fault. If the dam was located closerr to the falls at Highway No. 1, the vibrations could be higher than indicated in the study. If the dam was moved away from this fault, the effects of earthquake could decrease to the level used on the Rio San Juan damsites, assuming no other fault is found within 20 km of the site.

The Tamarindo damsite was critically affected by the C event, referenced to local faults of the Rio Tamarindo which had not been substantiated. If investigations find that a fault (or faults) lies in the Rio Tamarindo, careful study must be done on the activity of this fault prior to selection of this site for a dam. If the Tamarindo faults are not substantiated, it is possible that the damsite will then be critically affected by the A event from the Middle America Trench.

The studies of Panaloya and Tamarindo damsites with the C event as selected indicated problems with the analysis methods described in the USBR publication, "Method for Estimating Design Earthquake Rock Motions," cited previously. The analysis methods used by this report at very small epicentral distance involve the interpolation of Seed's curves, no attenuation for distance by the Spectral Scaling Method, and no possibility of constructing a response curve by the Earthquake Research Center Methods. Therefore, the critical accelerations for these damsites are probably invalid and could be even higher than shown. Depending upon the need for feasibility or design studies and the location of the critical faults, other methods of analysis should be used to analyze these damsites at such a later time.

Because each of the damsites will be subjected to very large ground motions, the choice of structure and its configuration were selected with care. Structures susceptible to vibration collapse, such as hydraulic fill embankments, were not used. Side slopes of embankments or excavations were held flat enough to resist vibrations and concrete structures laid out to eliminate large mass overhangs and inflexible connections or joints. Instrumentation of all structures was included in the designs and estimates.

As previously noted, due to the limited nature of this study and advances being made in seismic technology, any further study of this project should be accompanied by a complete restudy of seismic potentials.

Table B-4 - Maximum credible earthquakes

Event	Tectonic province or feature	Richter magnitude	Focal depth	Epicentral distance referenced to figure 3
A	Middle American Trench	8.5	30 km	Anywhere west of the assumed ℄ shallow focus trench events
B	Volcanic lineaments	8.0	100 km	Anywhere between the volcanic lineaments and the assumed ℄ shallow focus trench events
C	Near-surface events	7.0	5 km	Anywhere east of the assumed northeastern boundary faults of Nicaraguan Depression - 20 km maximum or distance to nearest north or northeasterly striking fault
D	Northeastern boundary faults of Nicaraguan Depression	8.0	100 km	Anywhere along assumed northeastern boundary faults of Nicaraguan Depression
E	Southwestern boundary faults of Nicaraguan Depression (Costa Rica)	8.0	100 km	Anywhere along assumed southwestern boundary faults of Nicaraguan Depression
F	East coast	7.5	100 km	Anywhere east of the assumed edge of east coast events

Table B-5 - Maximum credible earthquakes at damsites

San Isidro damsite. - Located at the Toro Rapids of the Rio San Juan about 14 km upstream from El Castillo

Event	Magnitude	Focal depth	Epicentral distance
A	8.5	30 km	145 km
B	8.0	100 km	75 km
C	7.0	5 km	20 km*
D	8.0	100 km	25 km
E	8.0	100 km	45 km
F	7.5	100 km	55 km

---

* Referenced to no local faults.

Panaloya damsite. - Located at the Rio Tipitapa, midway between Lake Managua and Lake Nicaragua

Event	Magnitude	Focal depth	Epicentral distance
A	8.5	30 km	90 km
B	8.0	100 km	20 km
C	7.0	5 km	10 km*
D	8.0	100 km	20 km
E	8.0	100 km	-
F	7.5	100 km	200 km

---

* Referenced to the falls on the Rio Tipitapa - the Tipitapa Fault.

Tamarindo damsite. - Located at the Rio Tamarindo about 8 km from the Pacific Coast

Event	Magnitude	Focal depth	Epicentral distance
A	8.5	30 km	45 km
B	8.0	100 km	0 km
C	7.0	5 km	5 km*
D	8.0	100 km	50 km
E	8.0	100 km	-
F	7.5	100 km	275 km

---

* Referenced to local faults of the Rio Tamarindo - unsubstantiated location.

Table B-6 - Design earthquakes at damsites

San Isidro damsite. - Located at the Toro Rapids of the Rio San Juan about 14 km upstream from El Castillo

Event	Magnitude	Focal depth	Epicentral distance
A	8.5	30 km	145 km
B	7.5	100 km	75 km
C	6.5	5 km	20 km*
D	8.0	100 km	25 km
E	7.5	100 km	45 km
F	7.0	100 km	55 km

* Referenced to no local faults.

Panaloya damsite. - Located at the Rio Tipitapa, midway between Lake Managua and Lake Nicaragua

A	8.5	30 km	90 km
B	7.5	100 km	20 km
C	7.0	5 km	10 km*
D	8.0	100 km	20 km
E	7.5	100 km	-
F	7.0	100 km	200 km

* Referenced to the falls on the Rio Tipitapa - the Tipitapa Fault.

Tamarindo damsite. - Located at the Rio Tamarindo about 8 km from the Pacific Coast

A	8.5	30 km	45 km
B	7.5	100 km	0 km
C	7.0	5 km	5 km*
D	8.0	100 km	50 km
E	7.5	100 km	-
F	7.0	100 km	275 km

* Referenced to local faults of the Rio Tamarindo - unsubstantiated location.

Table B-7 - Results of design earthquakes at damsites

Damsite	Event	Maximum ground acceleration	Response spectrum analysis 5 percent damping	
			Absolute acceleration	Frequency range
Sarapiqui	C	0.22 g	0.31	2.2-4.0 Hz
	D	0.07 g	0.18	1.4-2.1 Hz
Machado	C	0.22 g	0.31	2.2-4.0 Hz
	D	0.07 g	0.18	1.4-2.1 Hz
San Isidro	C	0.22 g	0.31	2.2-4.0 Hz
	D	0.07 g	0.18	1.4-2.1 Hz
Panaloya	C	0.48 g	0.42	2.0-3.0 Hz
Tamarindo	A	0.23 g	0.42	1.5-2.2 Hz
	C	0.58 g	0.47	2.0-3.0 Hz

TIPITAPA-TAMARINDO PROJECT

DESIGNS AND ESTIMATES MEMORANDUM

June 1977

The purpose of this memorandum is to provide the pertinent backup data concerning the designs and estimates for the Prefeasibility Report of the Tipitapa-Tamarindo Project, Nicaragua, Central America. These data would normally be presented in an Appendix to the Report, but to save time in the report preparation, it is felt that a memorandum would be adequate for this purpose.

The original concept of the Tipitapa-Tamarindo Project Study was as an alternative to the San Juan Project. When progress on the San Juan Study indicated its general infeasibility, however, it was decided to separate the Tipitapa-Tamarindo Study from it and evaluate it on its own merits. However, some of the data used for this study have been taken from the previous San Juan Report. Rather than repeat these data in this memorandum, reference is made to the specific Appendixes of the San Juan Report for elaboration of these subjects. If should be noted that the same cost reference date of January 1976 has been used.

Definition of Project Study

The original plan of development, as detailed in the October 1974 report on the "Tipitapa Project" by COMEC (Cia. Mexicana de Consultores en Ingenieria,

S. A.), Mexico, D. F., was to tie into the Rio San Juan Project and to utilize the waters of Lake Nicaragua for navigation and power generation.

This discussion of the proposed plan of development is greatly simplified from the original COMEC report, but the basic works consisted of the following:

1. San Isidro Dam to block flows from Lake Nicaragua down the Rio San Juan.

2. Panaloya Dam and associated works to pump water from Lake Nicaragua to Lake Managua. A lock would be provided to allow waterborne transportation between the lakes.

3. Tamarindo Dam and associated works to generate power as the water flows to the Pacific Ocean. Again, a lock was planned to connect Lake Managua to the Pacific.

The original charge for the study of the Tipitapa-Tamarindo Project was to bring the COMEC Study up to Prefeasibility Standards in conjunction with the Rio San Juan Study. The basic concepts of the COMEC Study has been retained in this study, with modifications studied to eliminate infeasible functions and problems revealed by more detailed topography and geologic investigations. Due to the emergency nature of power development required in Nicaragua, an alternative scheme to the Tipitapa-Tamarindo Project was also evaluated. This, the Brito Scheme, would eliminate the diversion of Lake Nicaragua waters into Lake Managua and instead would divert the flows directly into the Pacific Ocean for power generation via works constructed near Brito. Its location would basically follow the canal route of the 1970 study "The Atlantic-Pacific Interoceanic Canal Studies" by the U.S. Corps of Engineers, AEC, and Panama Canal Company.

Project Schemes

Two basic schemes were studied, the Tipitapa-Tamarindo Scheme and the Brito Scheme. Alternative layouts of these schemes were first analyzed to determine the most economical configuration of the necessary structures. The resulting major features are shown on the Location Map, Figure 1.

The major features of the Tipitapa-Tamarindo Scheme are as follows:

1. San Isidro Dam. - This structure would block the flow of the Rio San Juan and would be located across the Rio San Juan midway between the Rio Sabalos and the Toro Rapids. It would be a concrete overflow weir across the full width of the river with abutments of zoned earth construction.

2. Tipitapa features - located between Lake Nicaragua and Lake Managua. -

    a. Tipitapa pump entrance channel. - This canal would convey water from Lake Nicaragua to the forebay of the Libano Pumping Plant, a distance of about 24 km. It would leave the lake about 2.5 to 3 km southwest of the present mouth of the Rio Tipitapa and would go northwest through the swamp area and the Laguna Tisma. After crossing the lagoon it would enter the Rio Tipitapa and generally follow its course to the Libano site.

b. Libano Dam and Pumping Plant. - The dam and pumping plant would be built across the Rio Tipitapa just south of El Libano and about 3 km east of the town of Tipitapa. The main feature would be the pumping plant although a spillway would also be provided to release flood flows from Lake Managua into Lake Nicaragua as the Rio Tipitapa does presently. Abutments of zoned earth would complete the structure. No reservoir, as such, would be necessary for this structure.

c. Tipitapa pump exit channel. - This canal would convey the outflow of the Libano Pumping Plant westerly along the existing Rio Tipitapa channel and into Lake Managua. It length would be about 5.5 km.

3. Tamarindo features - located between Lake Managua and the Pacific Ocean. -

a. Tamarindo entrance channel. - This canal would convey the water from Lake Managua to the Tamarindo Reservoir. Its length would be about 12.5 km. It would leave the lake about 1 km north of the

Hacienda El Recreo and cross the new Leon Highway between the Haciendas La Ceiba and Las Brisas. It then continues generally southwest until it reaches the course of the Rio San Gabriel. It then follows the Rio San Gabriel, then the Rio Tamarindo into the reservoir area.

b. Tamarindo Dam, Reservoir, and Powerplant. - The Tamarindo Dam would be constructed across the Rio Tamarindo just upstream from the town of El Tamarindo. It would be an embankment dam, crest length about 4 km, of zoned earth construction and 'L' shaped configuration. It would lie astride the old Leon Highway which would be relocated to its crest. A powerplant would be constructed in the Rio Tamarindo channel, at the site of the recent Isla del Amor. Two dikes north of the dam would be necessary to close the reservoir, one of crest length 150 m but the other of 2.5 km. The small dike would be the location of the emergency spillway which would discharge into the Quebrada la Simarra. The dikes would be located just west of the Rio Paso de Don Diego and parallel to this channel. The reservoir would flood about 1500 ha and would necessitate the relocation of over 11 km of the railroad recently completed to Puerto Somoza.

c. Tamarindo tailrace channel. - This canal would convey this outflow of the Tamarindo Powerplant west into the Pacific Ocean. Its length would be about 8 km and it would generally follow the course of the Rio Tamarindo. Just north of the town of Puerto Somoza, however, it would swing to the west to ensure no degradation of the town and port.

The major features of the Brito Scheme are as follows:

1. San Isidro Dam. - The same as for the Tipitapa-Tamarindo Scheme, located on the Rio San Juan, midway between the Rio Sabalos and the Toro Rapids. It would be a concrete overflow weir and would block the flow of the Rio San Juan. Major floods on Lake Nicaragua would overtop the weir and discharge down the Rio San Juan.

2. Brito features - located between Lake Nicaragua and the Pacific Ocean. -

a. Brito entrance channel. - This canal would convey water from Lake Nicaragua to the Miramar Reservoir. Its length would be 18 km and it would leave the lake at the present mouth of the Rio las Lajas. It would generally follow the course of the Rio las Lajas, then the Rio Guiscoyol, for about 7.5 km. It then would cut through the continental divide and enter the reservoir via the course of the Rio Grande.

b. Miramar Dam, Reservoir, and Powerplant. - The Miramar Dam would be constructed across the Rio Brito about 1 km north east of the Hacienda Miramar. It would be an embankment dam, crest length about 1 km, of zoned earth construction. A powerplant would be built near its northwest abutment and an emergency spillway would be built on its southeast abutment. Its reservoir would flood about 1500 ha including portions of the drainage basins of the Rio Tola, Rio Grande, and the Rio Brito.

c. Brito tailrace channel. - This canal would convey the outflow of the Miramar Powerplant west into the Pacific Ocean, a distance of 6 km. The canal would follow the valley of the Rio Brito, exiting into the ocean just south of the mouth of the river.

Project Functions and Plan Formulation

The study of the Tipitapa-Tamarindo Project was limited in scope to the evalution of only the power generation and navigation functions. Navigation studies for the San Juan Project indicated that any expenditures for this function would be infeasible (see Appendix D of San Juan Project), so this function was eliminated from consideration. This left only the power function, so the studies proceeded as single-purpose schemes. Even a cursory examination of the schemes indicated that, using power as the only benefit, the Brito Scheme would be the more attractive. With this scheme more energy would be available for a lower capital investment. However, two important benefits would be realized with construction of the Tipitapa-Tamarindo Scheme. The diversion of fresh water through Lake Managua would cleanse the lake of its high mineral content and would also make high quality water available for irrigation of lands. A rough estimate of lands showed some gravity irrigation potential exists for approximately 50 000 ha of land around Lake Managua and around the northern end of Lake Nicaragua. This irrigation potential should be evaluated in terms of the extra cost of the Tipitapa-Tamarindo Scheme and the lost power involved before any final comparison to the Brito Scheme is made.

Design studies were limited to the following procedures:

1. Prepare preliminary scheme layouts, then evaluate the variable structure locations within each scheme to determine the optimum configuration. This was done by preparing reconnaissance-grade estimates for the various scheme configurations, for various flow capacities, and evaluating structures based upon their topography and foundation geology.

2. Prepare revised scheme layouts and then prepare cost curves for each scheme showing reconnaissance-level construction costs versus diversion capacity of the scheme. Both this study and the initial study were based upon preliminary hydraulic computations sizing the project features and alternatives.

3. Prepare revised hydraulic computations sizing the various project features to determine operating water surfaces, head losses, and invert grades.

4. Using the revised hydraulic computations the schemes cost curves were revised. These more accurate cost curves are then the result of this design study and can be used to determine project feasibility and optimizing capacities of each scheme.

Site Alternatives

The only alternative to the San Isidro Dam considered was a dam at the La Chorrera site. This is located about 40 km down the Rio San Juan from the San Isidro damsite. It is about 16 km upstream from the confluence of Rio San Carlos. This site would seem to have adequate abutments founded on steep hills and may be a completely adequate damsite. No geologic exploration was done at this site and it was eliminated from consideration mainly because the San Isidro topography and foundations seem almost ideal. Also, the topography of the La Chorrera site indicates that the streambed reaches a low elevation at sea level. Thus, the dam would have to be at least 35 m above streambed (vs. 7 m for San Isidro) and where the foundation of San Isidro is hard, fresh rock in the stream, the low elevation at La Chorrera indicates a good possibility of liquefiable sands in the channel. This could create construction problems similar to those recognized for those dams lower on the Rio San Juan (see Appendixes B and E of the San Juan Report).

Three alternative configurations were evaluated for the Brito Scheme. The first alternative would be the Miramar Dam and its entrance and exit channels previously described. The second would be the elimination of a dam from the scheme. This would involve construction of at least a 6- to 8-km extention of the entrance channel to act as a power canal supplying water to the Miramar Powerplant. This channel would be built in a side hill location and, although unestimated, was felt to be much more costly than the Miramar Dam. This alternative was eliminated without further study. The third alternative involved moving the dam from the Miramar site closer to the coast. An alternative damsite exists about 1 km off the beach and this alternative was explored for foundation depth and cost. Its main advantage would be the reduction of the length of the tailrace channel by about 5 km. Foundation exploration revealed a 15-m-thick layer of beach sand at a depth of about 5 m and rock foundation at a depth of about 40 m. Construction of this alternative, with its core extended to below the level of the beach sand, would cost $10,000,000 to $17,000,000 more than the Miramar Dam. This differential cost was calculated on the basis of the different dams (both zoned earth construction), required land for the reservoirs and features, and the different tailrace channel lengths required. Because of this cost differential, this alternative was eliminated from further studies.

All alternatives to the Libano site for the Tipitapa Pumping Plant were eliminated by consideration of topography and foundation exploration. Drilling was begun at the edge of Lake Nicaragua and generally moved northwesterly toward Lake Managua. The first holes in which rock was hit were holes 10, 11, and 12 near the Pasquier site. Topography indicated that this site would require a very long embankment (2 to 3 km) and the afterbay would flood some very productive land. Therefore, the Libano site was chosen both because of its shallow depth to rock for foundations and short embankment requirements. Further study and exploration may shift the pumping plant and its spillway and embankment slightly downstream to reduce the excavation required for construction. This should only be done after determination of optimum structure configuration and further foundation exploration. Both the Panaloya site and the Tisma site, which have been discussed by others, were eliminated from consideration, both because of lack of foundation on which to sit the pumping plant, the length of embankment, and the flooding of productive farm lands. Utilization of the Tipitapa Scheme for pump storage by utilizing reversible pump/generator units should also be considered in further studies depending upon the need for peaking power in the Managua area. This alternative was not considered in this study.

Three alternative configurations were evaluated for the Tamarindo Scheme. The first alternative would be the Tamarindo Dam and its entrance and exit channels previously described. The second would be the same basic scheme with the dam replaced by two smaller dikes to the east and within 1.5 km of the old Leon Highway. This alternative seems attractive because of the decrease in embankment construction required and the elimination of most of the highway relocation. Its main disadvantage would be the extra length of penstock required to reach the powerplant. The optimum location for the powerplant is near the Isla de Amor in the Rio Tamarindo. Pulling this plant to the east would require increasing amounts of rock excavation, both for the structure and its tailrace. Using the Isla de Amor location, the penstock for the second alternative must be about 2000 m longer than those through Tamarindo Dam. Depending upon the capacity of the system, the second alternative was estimated to be $50,000,000 to $100,000,000 more expensive than the Tamarindo Dam alternative. The third alternative would be the elimination of the Tamarindo Dam and its associated dikes and the construction of a power canal to supply water to the powerplant at the Isla de Amor. This alternative would require an extension of the entrance channel along the hillsides south of the Rio Tamarindo. This channel of about 8 km would be constructed in a side hill location and would involve mostly rock excavation and concrete lining. This canal would terminate on a bluff to the southeast of the powerplant, and penstocks about 1200 m longer than those for Tamarindo Dam would convey the water to the units. The savings of this alternative would be elimination of the Tamarindo Dam as well as its two associated dikes to the north. Also, the Leon Highway relocation would be eliminated as would most of the relocation required of the new railroad to Puerto Somoza. Land costs would also be reduced due to elimination of the reservoir. This alternative, however, was the most expensive, showing a differential cost over the Tamarindo Dam alternative of $90,000,000 to $140,000,000 depending upon the system capacity constructed.

Water Surface Elevation

The water surfaces used for the design of the various project features are shown in table TT-1. Notes on the determination of the water surface elevations are included in the table and a complete discussion is included in the Hydrology Report.

Scheme Layout and Design

The design effort for all features of the project was limited to those necessary to ensure adequate sizing of the structures and cost estimates within the accuracy required for a prefeasibility analysis. Basic assumptions concerning the lake and reservoir water surfaces and foundation properties were based upon the preliminary investigations available at the time. No attempt has been made to optimize the type of structure used, nor have specific structural computations been performed on structural components. Such computations should be done in the Feasibility Study. The main effort of this study has been to provide a workable scheme layout and to determine a reasonable estimate of costs.

1. San Isidro Dam

The San Isidro Dam would be located on the Rio San Juan midway between the Rio Sabalos and the Toro Rapids. Its basic functions would be to block the natural outlet of Lake Nicaragua, making its water available for diversion, and to allow discharge of flood waters from the lake into the Rio San Juan. As designed, it would be a concrete, ogee crested weir the full width of the present river channel with abutments of zoned earth construction (see figure TT-4). The topography used for the structural layout was surveyed by project forces using a plane table and alidade. It was then drawn to a scale of 1:1000.

The major portion of the reservoir of San Isidro Dam would be Lake Nicaragua with a section of the Rio San Juan flooded for a distance of about 40 km between the dam and the lake. The towns around the lake should not be affected by the stage of Lake Nicaragua; however, the river settlements and farms above San Isidro would be slightly encroached upon by the reservoir although not much more than at the historical levels. The most seriously affected would be the settlement of Sabalos at the Rio Sabalos. The reservoir would also back water up the Rio Medio Queso into Costa Rica. No large problems are anticipated in relocation or reservoir clearing due to the construction of San Isidro Dam. The discussion of relocations and reservoir clearing on the upper areas of the Sarapiqui and Machado Reservoirs give a more detailed discussion of these problem areas (see Appendix E of the San Juan Report) and would generally be valid for the San Isidro Dam.

Primary access to the damsite presently is by river. No major rapids lie between San Isidro and Lake Nicaragua. However, because of the Toro, Castillo, and Machuca Rapids downstream from the damsite, no access is presently available for heavy equipment from the east coast. The access methods discussed for the Sarapiqui and Machado damsites (see Appendix E of the San Juan Report) would not be feasible for this job. An all-weather road down the east coast of Lake Nicaragua to San Carlos is under construction and should be completed in 1978. The road could be extended to the damsite, but this would require about 40 km of construction plus two major bridges over the Rio Melchora and the Rio Sabalos. No cost was estimated for access road construction for the San Isidro Dam since it was anticipated that all major equipment could be barged across Lake Nicaragua to the damsite. Personnel access could be by the same means or by launch from San Carlos. Some local roads would be required to borrow areas and the camp, etc.

A construction camp would be required at the San Isidro Dam and it is anticipated that this camp could be utilized after construction for project housing and for the relocation of the settlement at Sabalos. Its cost is included in the scheme estimates.

Since the basic reservoir of San Isidro Dam is Lake Nicaragua, these lands have not been included for purchase. Easement arrangements would allow the lake fluctuations necessary for the project. Some of the private lands in the reservoir along the Rio San Juan and at the damsite and its camp would have to be purchased. Costs of these reservoir lands within the surcharge pool below Lake Nicaragua would be minor and have not been included in project costs.

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During normal operation of the project, the Rio San Juan would be dry below San Isidro Dam unless in high flood stage when the reservoir would spill. This dry stretch of river would extend downstream to the area influenced by the Rio Poco Sol. Also, the blocking of the flow of the Rio San Juan would probably make any navigation above the Machuca Rapids impossible without some modifications to the rapids. This would effectively isolate the historical important town of El Castillo from all access. The effects of this have not been evaluated environmentally or economically on the surrounding area. It may be necessary to maintain some minimum flow in the river. This could be done easily by providing an outlet in San Isidro Dam and/or some modification to the rapids. This should be decided in the feasibility study, keeping in mind that any water released decreases the amount of flow diverted.

The greatest climatic difficulty will be due to the rainfall at the damsite. The average rainfall at the San Isidro damsite is about 2000 to 2300 mm per year. February, March, and April are the driest months, but even they cannot be called dry. Although this amount of rainfall is less than at the Sarapiqui or Machado sites, the same construction difficulties would be experienced (see Appendix E of the San Juan Report). The construction costs estimated reflect these difficulties.

The geologic explorations at the damsite did not indicate any problems with the foundations at the site. The foundations at the site are generally hard basalt of the Coyol Formation, upper Miocene volcanic products. Thirteen holes were drilled at the San Isidro site, seven in the river channel, three on the right (south) bank, and three on the left (north) bank. The streambed holes indicated fresh, hard basalt at the surface, seemingly the riverflows have continually swept this rock clean of any weathering products or deposits. The abutments, however, have about 20 m of surface clays and ash, then about 10 m of basalt weathered in place above the fresh unweathered rock. It is anticipated that any concrete structures built would be excavated to bear on either fresh or lightly weathered rock while the embankments could be supported by the moderately or highly weathered materials with only the core extending to lightly weathered rock.

No search for construction materials in the area of San Isidro damsite has been made. Embankment materials should be available near the site. A rock borrow quarry would have to be established to provide fresh basalt for concrete aggregate and riprap. All aggregate for concrete would have to be manufactured; no gravel or rough graded sands are available in sufficient quantities near by. Type I cement is available in Nicaragua, but all Type II cement would have to be imported, probably through Corinto on the west coast, then shipped by truck to Granada. Then it would be barged across the lake and downriver to the damsite.

The seismic analysis done for San Isidro Dam is explained completely in Appendix B of the San Juan Report. In that study, San Isidro Dam would have been located at the Toro Rapids. Moving it upstream to its present damsite location should not affect the seismic accelerations. The design earthquakes evaluated are similar to those for Machado Dam of the San Juan Report (Appendix E) and are summarized below:

Design Event

Mag.	Epic. dist.	Focal depth	Maximum ground acceleration	Absolute acceleration	Frequency range
6.5	20 km	5 km	0.22	0.31	2.2-4.0 Hz
7.5	20 km	100 km	0.07	0.18	1.4-2.1 Hz

A complete study of the general area of the damsite should be done during the feasibility study. This should be done to determine the site geology and also to determine if any faults are located nearby which could affect the structure. This is especially important due to the hypothetical nature of the design event of the Nicaragua Depression used in the analysis.

The design of San Isidro Dam for its function as a diversion dam resulted in its layout as a concrete ogee crest across the full width of the river (400 m). Its foundation of fresh basalt at the streambed precluded any major structural excavation and its low height (crest elevation 33.0 m, streambed elevation 29.0 m) eliminated any necessity for cooling of the mass concrete. Its capability to discharge the inflow design flood limits the maximum water surface on Lake Nicaragua to elevation 33.6. At this reservoir level, the weir spillway would discharge 410 m^3/s. The abutments to the weir would consist of rolled earth embankments constructed to elevation 35.0, with a 3-m crest width, 3:1 upstream slope, and 2.5:1 downstream slope. The embankment would be supported by concrete retaining walls built perpendicular to the weir. The weir itself would be of a standard ogee shape with a vertical upstream face and a stabilized foundation of "B" hole grouting. No stilling basin would be necessary but a concrete apron would be provided at the downstream face to protect the rock when the weir spills.

Diversion for the construction of the San Isidro Dam would be a major problem. The estimated method would require a two-stage diversion scheme, segregating and drying up first one-half the channel construction area by construction of an earthen cofferdam then construction of that portion of the weir. Upon its completion, the cofferdam would be removed. Then another cofferdam would be constructed to dry out the remaining portion of the stream. The previously constructed weir would act to pass the riverflows while the remaining portion was completed. The diversion as estimated would be a major portion of the construction cost. It is possible that further studies may indicate that, due to the streambed surface rock being adequate for the weir's foundation, the weir could be constructed as preformed units onshore These hollow gravity sections could then be floated into place, sunk, and then backfilled with concrete and sealed with tremie concrete or grout. This would eliminate the cost of diversion although it could create other problems with sealing or forming of the concrete monoliths on the uneven streambed rock. This possibility should be evaluated during the feasibility study for the project.

2. Tipitapa Features

a. The Tipitapa entrance channel. - This channel, which would be dredged from Lake Nicaragua through the Tisma Swamp and Laguna would run generally northwest, to the Rio Tipitapa north of the Laguna and then up the river to the Libano Pumping Plant site. It would carry the diverted flow of Lake Nicaragua to the pumps at Libano and also to carry the discharge of the Libano spillway into Lake Nicaragua. It was designed and estimated for this prefeasibility study for three design flows, 500, 1,000, and 1,500 m^3/s. This range of flows was chosen to allow the construction of cost curves (see figure TT-22) and the maximum range was used to cover the possibility of pumping during off-peak hours. The topography and estimated alinement of the channel centerline are shown on figures TT-17, 18, 19, and 20. The topography used for this layout was produced under contract by Aerotecnica Centroamericana S. A. (ATECASA) at a scale of 1:5,000 and a 3-m contour interval.

The topography of the Tipitapa entrance chanenl can be divided into three distinct zones. The first 8 km runs through the Tisma swamp. This area is a zone of deep, sandy soil covered by grasses and swamp vegetation able to withstand periodic inundation when the rising level of Lake Nicaragua causes it to be submerged. It is utilized, depending upon the water level, mostly for cattle grazing and no relocations are contemplated except at the beach of Lake Nicaragua. This beach area is used for extensive vacation homes and any channel entrance location would dislocate some people. Jetties would be required at the entrance to the channel to prevent siltation of the channel by the littoral drift in the lake. These would be constructed to elevation 34.0 and would require facing of rock, concrete, or cut tuff blocks. It is not felt that operating roadways would be necessary along the channel banks since all maintenance of the channel would be by dredge. The dredge waste would be deposited evenly on the adjoining swamps to prevent bank sloughing into the channel and to allow future use for cattle grazing. A bridge would be required to carry the beach road over the channel (station 0+740). One span of this bridge should be removable to allow movement of the dredge into Lake Nicaragua for maintenance of the channel entrance. No problems of clearing, access, or climate would be involved in the construction of this portion of the channel.

The second zone is the 4 km through the Laguna de Tisma. The only problem contemplated with a dredge channel through this lake would be the waste disposal. In no case should the dredge waste be placed near the channel or near the exit of the present Estero Tipitapa. The best place for disposal would be to use the waste materials to fill in the southwestern edge of the Laguna up to present swamp grade. As with the first zone, no problems of clearing, access, or climate would be involved in this construction.

The third zone would be the remaining 12 km of channel running from the Laguna de Tisma to Libano Pumping Plant. This alinement generally follows the existing channel of the Rio Tipitapa except where the channel has been straightened to eliminate two long meanders in the present course. The land forms here are higher than the previous zones but again no problems should be experienced with a dredged channel. Some areas of broken tuff may be located in the last 2 km, especially near the pumping plant forebay; however, no difficulty should be experienced with a cutter head dredge. No relocations are expected in this reach, the principal facilities of Pasquire, Club Nautico, and Plywood de Nicaragua being located on the existing channel banks away from the alinement. To ensure that the new channel does not cut off access to these facilities, no operation roads are to be provided except between station 21+800 and the Libano Pumping Plant. The dredge waste should also not be placed in the old channel except where it would benefit the surroundings. Lands for waste disposal would be required to the southwest of the alinement where the dredge waste could be spread evenly with due regard to land use and drainage. A bridge would be provided at station 21+300 to provide cross-channel access to the existing roads. Also in this zone, five drainage inlet structures have been included in the estimate. These have not been shown on the drawings, but would allow side channel drainage to flow into the channel under raised portions of the operating roads without causing damage to the channel section.

The Tipitapa entrance channel would be a dredged, unlined channel without banks for operating roads for most of its 24 km length. Its design and estimation has been based upon the assumption that it would be capable of diverting 500, 1,000, or 1,500 m^3/s to the Libano Pumping Plant when Lake Nicaragua is at its minimum operating level, or top of inactive storage, elevation 31.7. A slope of 0.00007 m/m and a Mannings "n" = 0.035 has been used. Side slopes of 2:1 have been assumed. Channel properties are as follows:

	Flow capacity - cm		
	500	1000	1500
Depth of flow (m)	7.0	9.5	10.0
Base width of channel (m)	78.0	93.0	130.0
Area of channel (m^2)	644.0	1064.0	1500.0
Velocity of flow (m/s)	0.78	0.94	1.0

Based upon hydraulic computation for maximum losses in the channel at a flow of 500 cm and design conditions, the maximum total head loss between Lake Nicaragua and the Libano Pumping Plant forebay would be 1.3 m. Therefore, the normal operating forebay water surfaces at the Libano Pumping Plant would be elevation 33.0 maximum and elevation 30.4 minimum. These would be valid for Lake Nicaragua below its surcharge pool and without flood discharge over the Libano spillway. The operating roads from station 21+800 to the Libano Pumping Plant would be constructed to elevation 34.5. This would allow 0.9 m freeboard above the maximum level of Lake Nicaragua.

b. The Tipitapa pump outlet channel. - This channel runs along the course of the Rio Tipitapa from the Libano Pumping Plant to Lake Managua.

It would carry the pump discharge of the Libano plant to Lake Managua and also carry the flood flows from Lake Managua back to be discharged over the Libano spillway. It was designed and estimated, as was the Tipitapa entrance channel, for three design flows of 500, 1000, and 1500 m^3/s. The topography and estimated alinement of the channel centerline is shown on figure TT-21. The topography used for this layout was produced under contract by ATECASA at scale of 1:5,000.

The pump outlet channel was designed primarily as a line channel section. This was done for two reasons. First, lining of the channel reduces the amount of excavation and the width of the section. Since much of the excavation for this channel would be in tuff and also because of the channel's proximity to the town of Tipitapa, it was considered an advantage to reduce the width and amount of material to be excavated. The second reason is the Tipitapa Fault which crosses the channel near station 3+100. Lining over this section would help seal the fault from leakage and would allow rapid repair of the channel section should movement occur. A bridge would be located over the channel to carry the Pan American Highway (No. 1). This bridge should be equipped with stoplogs so the channel could be blocked off from Lake Managua and drained for maintenance or repair of its lined section. The bridge has been shown at the present crossing of the highway; however, construction of a new alinement for the highway is presently underway. The bridge would obviously be constructed at the new highway alinement, closer to Lake Managua. Another bridge would be provided at station 0+440 to allow access to the southern abutment of the Libano embankment. Although not indicated on the drawing, the estimate includes the cost of 12 drainage inlet structures to allow side channel drainage to pass under the raise operating roads and flow into the channel without damage to the section.

The concrete lining would extend from the lined afterbay of the Libano Pumping Plant to station 4+400. From 4+400 to 4+600 would be a lined transition section, gradually expanding to the wider unlined section. The unlined section would then continue the channel into Lake Managua where it would flare at its outlet. The channel would have operating roads on both sides proceeding from the Libano Pumping Plant to station 5+230.

The major construction problem of the Tipitapa pump outlet channel would be the disposal of the excavation wastes. No waste disposal areas have been located, but it is anticipated that suitable areas can be found to dispose of waste material east of the channel area. It is not recommended that the waste be disposed of in Lake Managua although if no other area can be found, this alternative could be studied. The channel section would be at least partially excavated and completely lined in the dry; however, diversion of flows from Lake Managua should be no problem. A simple cofferdam at the mouth of the Rio Tipitapa should effectively block any flow from the Lake. Ground water must be taken care of by well points and pumping as required and it should be noted that drains should be provided to relieve any differential hydrostatic pressure below the concrete lining. Relocation of residents, especially in the area of the town of Tipitapa, will be required, but since the construction camp for the Tipitapa features would probably be located there, this housing would be available after the construction period for resettlement. No problems of clearing, access, or climate would be involved in the construction of the channel although it is anticipated that the work could be scheduled to minimize interference from the rainy season from May through November.

The bridges of this channel could be subjected to very substantial seismic accelerations. The bridge for the Pan American Highway crossing would be very important to the operation of the project and to movement into Managua in the event of a major seismic event and it is recommended that it be designed for a design event close to maximum credible. Its proximity to the Tipitapa Fault would make this structure highly vulnerable.

The Tipitapa pump outlet channel would be a lined channel for all but 700 m of its 5300-m length. Operating roads would be located on banks on each side of the channel for almost its full length. Its design and estimation have been based upon the assumption that it would be capable of discharging 500, 1000, or 1500 m^3/s from the Libano Pumping Plant to Lake Managua. Lake Managua would be held at its normal operating level, or active conservation level, elevation 38.5. A slope of 0.00007 m/m would be used for both lined and unlined sections. A Mannings "n" of 0.014 has been assumed for the lined section and 0.035 for the unlined section. Side slopes of 1.5:1 and 2:1 have been assumed for the lined and unlined sections, respectively. Channel properties are as follows:

Lined section	Flow capacity - cm 500	 1000	 1500
Depth of flow (m)	7.0	9.5	10.0
Base width of channel (m)	29.0	34.0	47.5
Area of channel (m^2)	276.5	458.4	625.0
Velocity of flow (m/s)	1.81	2.18	2.40

Unlined section	Flow capacity - cm 500	 1000	 1500
Depth of flow (m)	7.0	9.5	10.0
Base width of channel (m)	78.0	93.0	130.0
Area of channel (m^2)	644.0	1064.0	1500.0
Velocity of flow (m/s)	0.78	0.94	1.0

Based upon hydraulic computation for losses in the channel at a flow of 500 cm and design conditions, the total head loss between the Libano Pumping Plant afterbay and Lake Managua would be 0.6 m. Therefore, the normal operating afterbay water surfaces at the Libano Pumping Plant would be elevation 39.1 maximum and elevation 38.5 minimum. These would be valid for Lake Managua below its surcharge pool. The operating roads on the channel banks would be constructed to elevation 40.5, 0.9 m freeboard above the maximum water surface of Lake Managua.

c. Libano Dam and Pumping Plant. - This dam and pumping plant would be constructed across the Rio Tipitapa just south of El Libano and about 3 km east of the town of Tipitapa. The main feature would be the pumping plant which was designed and estimated for pumping capabilities of 500, 1000, and 1500 m^3/s. An ungated spillway weir would also be provided to release floodflows from Lake Managua into Lake Nicaragua by reversing the flow in the Tipitapa pump outlet channel and the Tipitapa entrance channel. Abutments of zoned earth construction would complete the structure. No reservoir, as such, would be necessary for this structure; the channels would transition into lined forebay and afterbays at the pumping plant. The topography and generalized layout of this structure are shown on figure TT-21. The topography for this layout was produced under contract by ATECASA at a scale of 1:5,000.

Selection of the Libano site was dictated both by topography and geology. At this location the Rio Tipitapa leaves the steep walled channel and the contours open up into the broad plain of the Tisma Laguna area. Also, as indicated by drill holes No. 16, 17, and 18, competent tuff and tuff breccias are within 10 m of the surface to form the foundation for the plant. Since the forebay and afterbay of the pumping plant are entirely within the channel sections, this location requires the minimum amount of land. The only facilities that this structure would displace are the farm buildings of El Libano. An estimate of the land required for this structure as well as for the Tipitapa entrance channel and the Tipitapa pump outlet channel are included in the cost of this scheme. No problems with clearing of this site are anticipated since the area is primarily cleared land used for grazing.

Access to the Libano site would be no problem with the all weather Pan American Highway crossing the Rio Tipitapa within 4 km to the north and abundant farm roads throughout the surrounding area. Also the climate of the region will not hinder work except possibly in the 6-month rainy season of the region. Work during this period may be interrupted by the frequent heavy thundershowers which occur sometimes daily but with proper scheduling of the work and good drainage practices, no severe problem is anticipated. Rainfall in this area averages about 1000 mm per year. The year-round heat could be a greater problem requiring extensive cooling of the mass concrete which would be used in the pumping plant, spillway weir, and necessary training walls.

Due to the proximity of the construction site to the town of Tipitapa and to the city of Managua (20 km), only a small construction camp would be required. This would probably be located in Tipitapa and could be utilized in the future if built as a permanent camp. Especially for the common labor, local transportation would be required to and from Managua. This cost has been included in the estimate for the construction camp.

The geologic explorations at the damsite did not indicate any problems with the foundations at the site. Three holes were drilled along a line across the Rio Tipitapa just northwest of the pumping plant. These holes indicate that a dense, hard tuff breccia lies at about elevation 28 at the pumping plant site. One hole indicated that this is underlain by a hard cemented tuff at about elevation 22. This rock should be adequate for the structural foundations required. The abutment embankment cores should be founded in the tuff breccia and an adequate grout curtain constructed to cut off leakage under the structures.

No search for construction materials in the Tipitapa area has been made. It is anticipated that material for the embankments would be available locally from the excavtion of the structure site or the channels. Fine aggregate for the concrete construction would probably be available from the Tipitapa area on the shores of Lake Managua. Coarse aggregate, however, is not available locally. The closest known source of basalt of the Coyol Formation is 20 to 30 km to the northeast up the Pan American Highway in the foothills of the Cordillera Amerrisque. It would be necessary to set up an aggregate manufacturing plant at the quarry site and then truck the coarse aggregate to the Libano site. During the feasibility study of the project, location of borrow areas and testing of the materials should be done. Type I cement is available from the Canal Cement Company but Type II cement would have to be imported.

The seismic analysis done for Tipitapa Dam is explained completely in appendix B of the San Juan Report. In that study, Panaloya Dam would have been located about midway between Lake Managua and Lake Nicaragua or about 10 km from the Tipitapa Fault. The analysis of the design event of Richter magnitude 6.5 on the Tipitapa Fault at an epicentral distance of 10 km and a focal depth of 5 km yielded a maximum ground accleration of 0.48 g with an absolute acceleration from the response spectrum analysis (5 percent damping) of 0.42 g in the frequency range of 2.0 to 3.0 cycles per second. With the structures now located at the Libano site, the epicentral distance would decrease to about 3 km. No analysis has been done with this more critical distance but it is probable that the design seismic event of magnitude 6.5 on the Tipitapa Fault would cause a maximum ground acceleration of about 0.6 g at the Libano site. It is therefore very important that during the feasibility study a new seismic analysis be performed for the Libano structures, as well as the Pan American Highway bridge, and the effects of movement along the Tipitapa Fault be well understood prior to structural design and estimation of costs.

The pumping plant at Libano was situated across the existing channel of the Rio Tipitapa to minimize the excavation for the structure and the forebay and afterbay. The plant has been planned as an integral intake type with siphons at the pump discharge to provide positive backflow control. The pumps have been planned as vertical shaft centrifugal pumps with capacities of 62.5 cm (990 600 gal/min) and 125 cm (1 981 200 gal/min) to allow their estimation in the 500-, 1000-, and 1500-cm capacity schemes used. The maximum and minimum pumping heads are 8.7 m and 5.5 m, respectively, based upon the water surfaces of the forebay and afterbay. It was assumed that the pumps would be shut down during flood conditions. Pertinent pump information would be as follows:

Pump capacity	62.50 cm	125.00 cm
Synchronous speed	90.00 r/min	62.07 r/min
Specific speed	7722	7532
Centerline pump casing elevation	33.75	34.05
Impeller inlet diameter	3.68 m	5.25 m
Base of long radius suction tube elevation	18.62	12.47
Diameter of discharge conduit	5.10 m	7.25 m

Each unit would have a single rectangular intake protected by steel trashracks and bulkhead gates. It was assumed that two moveable bulkhead gates would be provided for all plants and would be set by a 15-short ton capacity gantry crane on the operating deck. The intake operating deck would be at eleation 34.5. The discharge for each unit would be a concrete siphon structure to provide positive protection against backflow in case of a rapid shutdown. The elevation of the siphon invert would be at 39.6, the maximum elevation of Lake Managua, and each would be provided with a vacuum breaker valve. One set of stoplogs would also be provided to dewater the siphons for maintenance. The top of the siphon structure would be at elevation 44.0 or 45.0 for the 62.5- and 125-cm units, respectively. The losses and cost of this relatively massive structure were felt to be justified when compared to alternative means of backflow protection for such large pump units.

The Libano Pumping Plant would be enclosed and a service and erection bay would be provided. Basic structure dimensions are as follows:

Plant capacity	500 cm	1000 cm	1500 cm
Units estimated	8 62.5 cm	16 62.5 cm	12 125.0 cm
Plant length	132 m	244 m	252 m
Plant width	20 m	20 m	24 m
Motor floor elevation	40.0	40.0	43.0
Plant roof elevation	56.0	56.0	62.0

Transformers and a switchyard have been estimated for each plant. It was assumed that one 3-phase transformer would be provided per unit plus one spare transformer. These would be located on the siphon structure. The switchyard, which would be located just to the northwest of the pumping plant, would have one switching bay per unit plus one transfer bay and two outgoing line bays. Transmission lines beyond the switchyard have not been included in the cost estimates made in the memorandum but they have been estimated and are included in the Power Memorandum.

The spillway at Libano has been provided to only release emergency flows from Lake Managua into Lake Nicaragua and would be located along the axis just to the southwest of the pumping plant. It is very likely that it would never spill since normal floods of Lake Managua could be controlled by decreasing pumping at Libano and normal discharge through the Tamarindo Features. The spillway has been designed as an ungated ogee weir, 150 m long with its crest elevation at elevation 39.4, 0.3 m above the maximum operating level of the Libano afterbay. Channels to the spillway from the forebay and afterbay would be provided to carry the flood flows to and from the weir. The weir would be founded on the tuff breccia at about elevation 25. The intake and discharge channels would not be excavated to rock since any spills would be very rare. Excavation of the intake channel would be to elevation 39.2 and of the outlet channel to elevation 33.2. Even with the inflow design flood on Lake Managua, flows over this weir are very low (maximum discharge 40.0 cm), and it should be possible to reduce its length substantially in further studies. Elimination of this spillway should be carefully considered, however, in relation to its cost against the consequences of leaving the Libano structures unprotected.

The embankments to close the afterbay and to provide access roads would be of zoned earth construction. A 10-m crest width has been used with 3:1 upstream slope and a 2.5:1 downstream slope. It is anticipated that the rolled earth core would be extended into the tuff breccia and a continuous grout curtain cutoff would be provided under the embankments, the spillway crest, and the siphon structure of the pumping plant.

Those embankments used only to support access roads would be constructed of free draining materials and would be unzoned. The minimum embankment elevation would be 41.0 to provide 1.4 m of the freeboard over the maximum water surface elevation on Lake Managua but the embankments would rise to the elevation of the siphon structure to allow access to the pumping plant. Concrete retaining walls would be built to support the embankment at the pumping plant forebay and afterbay and also at the spillway.

Diversion for the construction of the Libano Pumping Plant structures would not be a significant problem. The Rio Tipitapa does not normally carry any flow so small earthen cofferdams could easily isolate the structure site. The deep excavations would require dewatering but this would be no problem. Proper drainage and pumping would be required to ensure dry foundations.

3. Tamarindo Features

a. The Tamarindo entrance channel. - This channel would be excavated from Lake Managua to the Tamarindo Reservoir. After leaving the lake, it runs generally southwest cutting through the continental divide (elevation about 57) where it crosses the Ferrocarril del Pacifico de Nicaragua (national railroad), a distance of 2.5 km from the lake. It continues to the southwest until it reaches the Rio San Gabriel. It then generally follows the Rio San Gabriel, then the Rio Tamarindo to its outflow in the reservoir. It was designed and estimated for this prefeasibility study for four design flows, 250, 500, 750, and 1000 m^3/s. This range of flows was chosen to allow the construction of cost curves (see figure TT-23) and the maximum range was used to cover the possibility of a system to produce peaking power. The topography and estimated alinement of the channel centerline are shown of figures TT-9 and 10. The topography used for this layout was produced under contract by ATECASA at a scale of 1:5,000 and a 3-m contour interval.

The first 7 km of this channel would be constructed through the Cieba Mocha area and would be in rather deep cut (approximately 30 m maximum). To minimize the excavation and to prevent leakage in this mostly rock cut, this sectionof the channel would be lined. It is felt that although excavation through this area would be deep, it would be no great problem. The tuffs of the area should be rippable so little blasting would be necessary. Seismic testing for rippability should be done during the feasibility study to check this assumption.

A jetty would be built just southeast of the unlined entrance section in Lake Managua to prevent siltation of the channel and to protect the entrance from wave damage. It would be constructed to elevation 41.0 and would be faced with rockfill, concrete, or cut tuff blocks. Immediately thereafter, a lined transition structure would be provided to enter the lined channel section. Throughout the lined section, operating roadways would be provided on banks built on both sides of the channel. Three bridges have been estimated for this lined section, the first being a highway bridge to carry the New Leon Highway over the channel at station 2+130. To block off the remaining 5 km of lined channel, it was decided to equip this bridge with stoplogs. The canal beyond this bridge could then be dewatered for maintenance. Due to the great depth of this bridge, however, and the upstream 2 km of lining, which could not be dewatered, consideration should be given to providing a separate stoplog structure at the lined inlet transition structure at station 0+250. This should be reviewed during the feasibility study. The other two bridges would be for the Ferrocaril del Pacifico de Nicaragua. The first, at station 2+500, would carry the existing railroad over the channel. The second, at station 7+230, would be at the beginning of the lined outlet transition into the unlined section and would carry the relocated railroad south out of the reservoir area (see figure TT-11). Also included in the estimate for this section, although not shown on the drawings, are the costs for 10 drainage inlet structures to allow side channel drainage to pass under the raised operating roads and to flow into the channel without damage to the section.

The last 5.5 km of the channel would be unlined and would leave the continental divide area and follow river channels into the reservoir area. In this section operating roads would be built on banks on both sides of the channel until the channel would flare into the reservoir at station 12+200. Also, from a bridge which would be built at station 8+250, the road which runs from San Gabriel to Casa Blanca would be relocated to the south side operating road to about station 10+800 where it would swing away to join the existing road. Nine drainage inlet structures have been estimated for this portion of the channel to allow side channel drainage into the channels. This estimate was based upon preliminary assumptions, however, and can probably be substantially reduced in the feasibility study.

The biggest problem in the construction of the Tamarindo entrance channel would be the disposal of the excavated material. Between 8 000 000 and 15 000 000 m^3 of rock and common material would be excavated depending upon the channel discharge capacity built. Much of this material would be wasted although some could be used in the jetty and in the operating roadway banks along the unlined section. No disposal areas for waste have been located and, due to the preponderance of rock in the excavated material, this could be an important consideration. It may be posible to utilize much of the waste for embankment materials for Tamarindo Dam and the dikes, although this consideration with its necessary haul road has not been evaluated.

No serious problems of relocation of families, access, or climate would complicate construction of the Tamarindo entrance channel. The area is utilized for agriculture and livestock grazing by large haciendas, some of which may need relocation. Also some small farms and homes of the local campesinos would require relocation. Many roads exist throughout the area which would facilitate access for construction. Rainfall in the area occurs in the 6-month rainy season and averages about 1500 mm per year. Very slight difficulty should be experienced during construction as long as adequate drainage provisions are made.

The railroad relocation would involve one section of construction 8.8 km long to move the rail line south out of the reservoir. A second section of construction 2.5 km long would be necessary to bring the railroad past the dam. The alinement and ground profile are shown in figures TT-11 and 12.

The Tamarindo entrance channel would be a lined channel for its first 7 km. Its last 5.5 km into the Tamarindo Reservoir would be unlined. Its design and estimate have been based upon the assumption that it would be capable of diverting 250, 500, 750, or 1000 m^3/s to the Tamarindo Reservoir when Lake Managua is at its normal operating level of elevation 385. A slope of 0.000075 m/m would be used for both lined and unlined sections. A Mannings "n" of 0.014 has been assumed for the lined section and 0.035 for the unlined section. Side slopes of 1.5:1 and 2:1 have been assumed for the respective sections. Channel properties are as follows:

	Flow capacity - cm			
Lined section	250	500	750	1000
Depth of flow (m)	6.0	8.0	10.0	11.5
Base width of channel (m)	16.8	20.3	19.6	19.9
Area of channel (m^2)	154.5	258.5	346.0	427.2
Velocity of flow (m/s)	1.62	1.93	2.16	2.34

	Flow capacity - cm			
Unlined section	250	500	750	1000
Depth of flow (m)	6.0	8.0	10.0	11.5
Base width of channel (m)	45.5	55.5	55.5	57.5
Area of channel (m^2)	345.0	572.0	755.0	925.8
Velocity of flow (m/s)	0.73	0.87	0.99	1.08

Based upon hydraulic computation for losses in the channel at a flow of 750 cm and design conditions, the total head loss between the Lake Managua and the Tamarindo Reservoir would be 1.3 m. Therefore, the normal operating forebay water surfaces at the Tamarindo Powerplant (Tamarindo Reservoir) would be elevation 38.5 maximum and elevation 37.2 minimum. These would be valid for Lake Managua below its surcharge pool. The operating roads on the channel banks would be constructed to elevation 42.5, 1.0 m freeboard above the maximum water surface of Tamarindo Reservoir.

b. The Tamarindo tailrace channel. - This channel, of a little more than 8 km in length, would basically straighten, widen, and deepen the channel of the Rio Tamarindo to carry the outflow of the Tamarindo Powerplant into the Pacific Ocean. After the damsite area it generally would cut through flat areas of tidal marsh, past salt beds and mangrove swamps, into the Estero Rio Tamarindo. Except at the afterbay of the Tamarindo Powerplant, it would be a dredged channel. It would be unlined. It was designed and estimated for this prefeasibility study for the design flows of 250, 500, 750, and 1000 m^3/s to allow the construction of cost curves (see figure TT-23). The topography and estimated alinement of the channel centerline are shown on figures TT-15 and 16. The topography used for this layout was produced under contract by ATECASA at a scale of 1:5,000 and a 3-m contour interval.

The first 4 km of the channel would follow the basic river channel except where it would cut off a series of large meanders just before it would enter the Estero. These meanders mark the entrance of the Quebrada

La Simarra which would be utilized to carry the discharge of the emergency fuse plug spillway dike. An entrance transition would be dredged in this location (about station 2+400). No other drainage inlets need be provided since no operating roadway banks would be constructed.

After entering the Estero Rio Tamarindo at about station 3+500 the channel would swing to the south to follow the tidal channel. Instead of following this channel into the Pacific, however, it was decided to dredge a new channel through the peninsula of mangrove swamp to take the flow into the ocean through a new channel. This would be done to minimize the impact of the flow on the town and port of Puerto Somoza. It may be possible that this new channel could be a problem and cause silting of the port at Puerto Somoza and severe changes of the estuary environment. In this case, it should not be built; this should be studied further in a feasibility study. It has been planned to provide a jetty at the outlet transition of the channel into the ocean to protect against wave damage to the outlet. This would be constructed to elevation 4.0 and built completely of rockfill or concrete monoliths. It should be noted that no topography of the peninsular area was available at the 1:5,000 scale so the topography shown was interpolated from the existing 1:50,000 scale maps. No banks would be provided for operating roads. Maintenance of the Tamarindo tailrace channel would be done by dredge.

The construction of the channel would be affected by the tidal fluctuation of about 3 m. This would not seriously interfere with the construction.

Prior to dredging, some clearing of the channel alinement would be necessary through the mangrove areas. Also some relocations of people living along the alinement would be necessary; however, no estimate of the number of families is available. Disposal of dredge waste would be a major problem. This material should nto be disposed of without care for the uses and drainage of the surrounding areas. Much of this material would contain ocean minerals and salt and its use for land fill could be restricted. It may be necessary to barge the waste from the site. No costs for this extra handling have been included; it was assumed that waste disposal areas would be located nearby.

The Tamarindo tailrace channel would be a dredged, unlined channel of more than 8 km in length. No operating roads would be required. Its design and estimate have been based upon the assumption that it would be capable of discharging 250, 500, 750, or 1000 m^3/s from the Tamarindo Powerplant to the Pacific Ocean when the ocean is at its lowest tide level. The tidal fluctuation of the Pacific Ocean is between elevation 1.5 m maximum and elevation -1.9 m minimum (mean elevation - 0.3 m) based upon the recorded tidal records of the port of Puntarenas, Costa Rica, corrected to Puerto Somoza. The effects of the estuary or the channel upon this tidqal fluctuation are unknown. It may be possible that some magnification or even some damping of the tidal effect would affect the tailwater elevation. A channel slope of 0.000075 m/m and a Mannings "n" of 0.035 have been used, with channel side slopes of 2:1. Channel properties are as follows:

	Flow capacity - cm			
	250	500	750	1000
Depth of flow (m)	6.0	8.0	10.0	11.5
Base width of channel (m)	45.5	55.5	55.5	57.5
Area of channel (m^2)	345.0	572.0	755.0	925.8
Velocity of flow (m/s)	0.73	0.87	0.99	1.08

Based upon hydraulic computations for losses in the channel at a flow of 750 cm and low tide level, the total head loss between the Tamarindo Powerplant afterbay and the Pacific Ocean would be 0.2 m. Therefore, the normal operating afterbay water surfaces at the Tamarindo Powerplant would be elevation 1.7 maximum and elevation -1.9 minimum. The maximum elevation shown would be a little high since the channel design was based upon low tide elevation and with high tide level the area of flow would be larger and the velocity lower. It is not felt that this would be significant.

c. The Tamarindo Dam and Powerplant, plus the reservoir dikes. - The Tamarindo Dam would be a zoned earth embankment structure built across the Rio Tamarindo. In its present location, it would require relocation of about 4 km of the Old Leon Highway which would be relocated to the dam crest. The Tamarindo Powerplant would be constructed at its toe at the site of the Isla de Amor. The intake to the powerplant would be a concrete structure located in the upstream face of the dam embankment and connected to the crest by an operating bridge. The intake structure and the powerplant would be connected by steel penstocks, encased in concrete, and built by cut and cover methods. The embankment, powerplant. and road relocation are shown in figure TT-14. Two dikes, north of the dam, would be required to close the reservoir. One would be of crest length 2.5 km while the other would have a crest length of only 150 m. This smaller dike would be the location of the emergency spillway of fuse plug design, which would discharge flood flows into the Quebrada La Simarra. These dikes are shown in figure TT-13. The topography for these layouts and profiles was produced under contract by ATECASA at a scale of 1:5,000 and a 3-m contour interval.

The location and configuration of the "L" shaped Tamarindo Dam were dictated by topography and geology. As one moves up the Rio Tamarindo from the Pacific Ocean, the foundation rock o[illegible]uff first approaches the surface near the Isla de Amor. Location of the powerplant west of this site would require very deep foundation excavation to found the powerplant on rock. On the other hand, moving the powerplant to the east would eliminate any problem of foundation for that structure but would require the construction of the afterbay and the extension of the tailrace in rock. For this reason the Isla de Amor was selected as the optimum powerplant site. Various alternative dam location studies indicated that the embankment size was relatively unimportant compared to the cost of penstocks so the dam configuration used was selected. This gives the shortest penstock lengths and also closes the Rio Tamarindo canyon between the closest available abutments.

The dike locations, just west of and parallel to the Rio Paso de Don Diego, close the existing saddles in the hills on the northern edge of the reservoir. Both dikes would be low embankments of zoned earth. Selection of the small dike for the emergency spillway would eliminate the need for a bridge over the spillway which would be required if a spillway was provided at the Tamarindo Dam. The very rare spilling required for this structure lent support for a fuse plug design. The design used for this structure would allow the upper portion of the dike to fail when the reservoir water surface reaches elevation 40.5. The dike would then fail to a stabilized apron at elevation 39.0, allowing discharges to pass into the Quebrada La Simarra. After the reservoir water surface drops sufficiently, the upper portion of the dike would be rebuilt.

Other than the highway and railroad relocations required, little problem exists for existing property. The small town of El Tamarindo would be severely affected and it probably would require complete relocation as would the haciendas located in the reservoir. Costs for purchase of lands have been included in the estimate. No problems of land clearing are anticipated although some trees are located within the reservoir area. Most lands are used for agriculture and cattle grazing.

Access to the Tamarindo damsite would be primarily by the Old Leon Highway. The existing railroad could also be utilized, especially if it was decided to haul the embankment materials from the Ceiba Mocha area. The adequacy of the roadbed for such heavy use must be checked prior to its use. The climate of the region should not hinder work except possibly during the 6-month rainy season. Work during this period may be interrupted by the frequent heavy thundershowers which occur sometimes daily but with proper scheduling of the work and good drainage practices, no severe problem is anticipated. Rainfall in the Tamarindo area averages about 1500 mm per year. The year-round heat could be a greater problem, requiring cooling of the mass concrete used in the powerplant and power intake structure.

No facilities for housing of the construction crew are available near the damsite so an extensive construction camp would be required. This could be located near the Leon Highway and could be utilized in the future if built as a permanent camp. Costs for this camp are included in the estimate.

The foundation exploration at the damsite was located to the east of the present powerplant location and all the holes drilled (Nos. 18 through 23) indicated rock at or near the ground surface. These surface rocks are tuffaceous rhyolite or rhyolite tuff, underlain by tuff and tuff breccia. These rocks seem to dip away from the surface near the Isla de Amor and, although no drilling was performed in this location, the powerplant was sited here to ensure adequate rock foundations and to minimize rock excavation in the tailrace channel. Neither the dam or the dike foundations would require deep excavation to support the embankment cores on rock. The dam would require a continuous grout curtain to complete closure. No grout curtain has been estimated for the dikes. Further studies may indicate that a grout curtain would be required. A high allowance for unlisted items and contingencies was added to take care of this eventuality.

No search for construction materials in the Tamarindo area has been made. It is anticipated that material for the embankments would be available from the Ceiba Mocha area of the Tamarindo entrance channel excavations. Getting the materials to the dam and dike embankment areas could be a problem. This was discussed as an access problem. Concrete fine and coarse aggregates would be a severe problem. Beach sand is available from the Pacific Coast and could be cleaned and shipped from the Puerto Somoza area. The beach sand would be relatively poorly graded, however, so another source of fine aggregate must be found. The tuff or rhyolite available locally are unsuitable for concrete aggregate. The closest source of suitable basalt which could be crushed for aggregate is located in the Cordillera Amerrisque east of Lake Managua. No corridor to this area exists north of Lake Managua so the material must either be barged across the lake or trucked around the south end through the Managua area. It would be necessary to set up an aggregate manufacturing plant at the quarry site and then ship the processed aggregate to the construction area. During the feasibility study of the Project, location of borrow areas and the testing of the materials should be done. Type I cement is available from the Canal Cement Company but Type II cement would be imported.

The seismic analysis done for Tamarindo Dam is explained completely in appendix B of the San Juan Report. In that study, Tamarindo Dam would have been located about 8 km from the Pacific Ocean. The shift of damsite location should not be critical to the seismic analysis. The design earthquakes evaluated are summarized as follows:

Mag.	Epic. dist.	Focal depth	Maximum ground acceleration	Absolute acceleration	Frequency range
8.5	45 km	30 km	0.23 g	0.42 g	1.5-2.2 cps
7.0	5 km	5 km	0.58 g	0.47 g	2.0-3.0 cps

The 7.0 magnitude event is referenced to anticipated faults along the Rio Tipitapa. These faults have not been substantiated and because of the great effect this event would have upon any structure, further investigation is imperative. If no faults are discovered within 20 km of the damsite, the 8.5 magnitude event of the Middle American Trench would become critical. It is imporatnt that during the feasibility study more exploration for faults be undertaken and if necessary, a new seismic analysis be performed. Due to the height of Tamarindo Dam and the large accelerations anticipated, advanced techniques of seismic design should be employed to ensure adequacy of the structure during design.

The Tamarindo Powerplant would be located at the downstream toe of Tamarindo Dam at the present Isla de Amor in the Rio Tamarindo. It would be connected to the concrete intake structure by penstocks of steel encased in concrete. The powerplant designs were based on the system capacity used for studies of the channels. This necessitated powerplant estimates for capacities of 250, 500, 750, and 1000 m^3/s. These estimates allowed construction of the cost curves shown in figure TT-23. The units used for these designs were based on discharge capacity rather than generation capacity. Two units were estimated, one for a design flow of 125 m^3/s and the other for a discharge of 250 cm. Only the 125-cm unit was sized since this information was only required for general site configurations. The maximum and minimum heads on the units would be 40.4 m and 35.5 m, respectively, based upon the water surfaces in the Tamarindo Reservoir and the powerplant afterbay of the Tamarindo tailrace channel. The design head used in the estimate was based upon preliminary design information and was 34.8 m. This is less than the average of the maximum and minimum heads so the estimate should be revised for further studies to a design head of 38.0 m. Time did not allow this correction in these studies. Vertical shaft, Francis-type turbines were estimated. Turbine and generator information would be as follows:

Flow capacity	125 cm	250 cm
Horsepower	50,000	100,000
Synchronous speed	150.0 r/min	102.9 r/min
Specific speed	89.9	
Generator rating	35.4 MW	70.8 MW
Unit kVA	52,400	104,800

The Tamarindo Powerplant would be enclosed and a service and erection bay would be provided. The structure was not dimensioned since no size for the plant was required for the estimate. For the flow capacities estimated, the following units were used:

250 cm - 2 - 125-cm units
500 cm - 4 - 125-cm units
750 cm - 3 - 250-cm units
1000 cm - 4 - 250-cm units

Transformers and a switchyard have been estimated for each plant. It was assumed that one 3-phase transformer would be provided per unit plus one spare transformer. These would be located on a transformer deck on the upstream side of the plant. The switchyard would be located near the present town of El Tamarindo. It was assumed to have one switching bay per unit plus one transfer bay and two outgoing line bays. Transmission lines beyond the switchyard have not been included in the cost estimates made in the memorandum but they have been estimated and are included in the Power Memorandum.

To standardize the estimates, only one penstock was estimated. This was an 8.75-m-diameter steel conduit, 1-inch thick, encased with reinforced concrete. It was assumed that one penstock would service each 250-cm unit. The same penstock would service each two 125-cm units and would bifurcate into two 6.50-m-diameter conduits to reach the unit except for the 250-cm scheme where two 6.5-m penstocks would be used. Downstream guard gates would only be provided with the 125-cm units because of the bifurcation and they would be 6.5-m-diameter butterfly valves. At the upstream end of each penstock would be a wheel-mounted guard gate and a bulkhead gate each 9.5 m high by 6.4 m wide. Only one bulkhead gate would be provided. The penstocks and their encasement would be constructed in cut and cover sections.

The penstock intake structure would be of the drop inlet type with a 12-m-wide separate bay to serve each penstock intake. Each bay would be protected by a steel bar-type trashrack laid over the intake portal. The intake would stay in rectangular section through the penstock intakes and the bulkhead and wheel-mounted guard gates. The intake structure would rise to a service deck above maximum water surface from which the gates would be operated and pulled for maintenance. The service deck would be connected to the dam crest by an operating bridge. A 75-short-ton-capacity gantry crane would be provided on the service deck to move the bulkhead gate and for maintenance of the wheel-mounted gates and trashracks.

The embankment section for the Tamarindo Dam and the long dike to the north have been estimated as a standard zoned earth section. The crest elevation of these two structures would be at elevation 42.5 giving 1.0 m of freeboard above the maximum reservoir water surface. A crest width of 10.0 m was used with 3:1 upstream slope and 2.5:1 downstream slope. The clay and silt compacted core would rest on rock and a continuous grout curtain would be provided to seal the foundation. A filter would be provided on the downstream face of the core to help drain the section. It was anticipated that slope protection would be provided by the outer zones of rock and sand materials. It may be necessary to provide another facing on the upstream slope; for this, the cut tuff blocks produced in the area may be adequate. Due to the seismic accelerations, it also may be necessary to provide flatter slopes of waste materials in the deeper dam sections. No analysis has been made and this should be studied during the feasibility study.

The fuse plug dike would be built as a wide apron, faced with tuff blocks to form the permanent section. The crest of this broad-crested weir would be at elevation 39.0. Upon this apron, the fuse plug portion of the dike would be built to elevation 40.5 giving 0.9-m freeboard above the maximum elevation of Lake Managua. With the design storm on the Tamarindo Reservoir, the reservoir water surface would rise above elevation 40.5, causing the fuse plug to fail and allowing the flow to discharge over the spillway into the Quebrada La Simarra. With the reservoir at its maximum water surface elevation 41.5, the spillway would discharge 940 m^3/s.

Diversion for the construction of the dam, powerplant, and dikes should be no problem. The flows of the Rio Tamarindo at the damsite will require diversion during the construction of the embankment. No studies of diversion floods have been done but it is possible that one or two of the power penstocks could be utilized to carry the flows past the embankment. A complete diversion study should be undertaken during the feasibility phase of this project. It is anticipated that some cofferdams will be required with flumes or conduits used to pass the flows. Well points may be required to dry out the foundations of the powerplant and also protections on the downstream side would be required to protect against the tidal encroachment.

4. Brito Features

Due to time limitations and because the primary interest of the Nicaraguan Government is in the Tipitapa-Tamarindo Schemes, the writeup on the Brito

Scheme has been limited to a summary of design data which formed the basis of the estimate.

a. The Brito entrance channel. - This channel would be unlined for its first 3.8 km, from its entrance at Lake Nicaragua. Two jetties are planned to protect the entrance. They would be built to elevation 34.0. One bridge would be in this section to carry the Pan American Highway across the new channel at station 1+040. From station 3+800 to 14+500 the section would be lined. This includes both the entrance and outlet transitions. Bridges would be constructed at stations 4+030 and 10+280. The bridge at 4+030 would be equipped with stoplogs to allow the lined channel section to be dewatered for repair and maintenance. The last 4.2 km of channel would be unlined until its outlet into Miramar Reservoir. The topography and estimated alinement of the channel centerline are shown on figures TT-5, 6, and 7. The topography used for this layout was produced under contract by ATECASA at a scale of 1:10,000 and a 5-m contour interval. Thirty-three drainage inlet structures have been estimated along this channel to allow side channel drainage into the channel. Operating roads on both channel banks would be provided along the full channel length.

The design and estimate of the Brito entrance channel have been based upon the assumption that it would be capable of diverting 250, 500, 750, or 1000 m^3/s to the Miramar Reservoir when Lake Nicaragua is at its minimum operating level, or top of inactive storage, elevation 31.7. A slope of 0.00007 m/m would be used for both lined and unlined sections. A Mannings "n" of 0.014 has been assumed for the lined section and 0.035 for the unlined section. Side slopes of 1.5:1 and 2:1 have been assumed for the respective sections. Channel properties are as follows:

Lined section	Flow capacity - cm			
	250	500	750	1000
Depth of flow (m)	5.0	7.0	8.5	9.5
Base width of channel (m)	26.0	29.0	30.5	34.0
Area of channel (m^2)	167.5	276.5	367.6	458.4
Velocity of flow (m/s)	1.49	1.81	2.04	2.18

Unlined section	Flow capacity - cm			
	250	500	750	1000
Depth of flow (m)	5.0	7.0	8.5	9.5
Base width of channel (m)	69.0	78.0	84.0	93.0
Area of channel (m^2)	395.0	644.0	858.5	1064.0
Velocity of flow (m/s)	0.63	0.78	0.88	0.94

Based upon hydraulic computations for losses in the channel at a flow of 750 cm and design conditions, the total head loss between the Lake Nicaragua and the Miramar Reservoir would be 1.5 m. Thereafter, the normal operating forebay water surfaces at the Miramar Powerplant (Miramar Reservoir) would be elevation 33.0 maximum and elevation 30.2 minimum. These would be valid for Lake Nicaragua below its surcharge pool. The operating roads on the channel banks would be constructed to elevation 36.5 giving 1.0 m freeboard above the maximum water surface of Miramar Reservoir.

b. The Brito tailrace channel. - This channel would be a dredged, unlined section for its full length of just over 6 km. The topography and estimated alinement of its centerline are shown on figure TT-8. The topography used for this layout was produced under contract by ATECASA at a scale of 1:10,000 and a 5-m contour interval. No roadways on the channel banks would be provided since the tailrace channel would be maintained by dredge when necessary. An entrance transition would be dredged on the south side of the channel at about station 1+000 to allow entrance of the spillway discharge channel. This would be the only drainage inlet required in the tailrace channel. A jetty to elevation 4.0 at the outlet transition into the Pacific would provide protection from the ocean waves and currents.

The design and estimate of the Brito tailrace channel have been based upon the assumption that it would be capable of discharging 250, 500, 750, or 1000 m^3/s from the Miramar Powerplant to the Pacific Ocean when the ocean is at its lowest tide level. The tidal fluctuation of the Pacific Ocean is between elevation 1.5 m maximum and elevation -1.6 minimum (mean elevation -0.4 m) based upon the recorded tidal records of La Union, El Salvador, corrected to San Juan del Sur, Nicaragua. The effects of the new channel, located about 13 km up the coast from San Juan del Sur, upon this tidal fluctuation are unknown. It may be possible that some magnification or even some damping of the tidal effect would affect the tailwater elevation. A channel slope of 0.00007 m/m and a Mannings "n" of 0.035 have been used, with channel side slopes of 2:1. Channel properties are as follows:

	Flow capacity - cm			
	250	500	750	1000
Depth of flow (m)	5.0	7.0	8.5	9.5
Base width of channel (m)	69.0	78.0	84.0	93.0
Area of channel (m^2)	395.0	644.0	858.5	1064.0
Velocity of flow (m/s)	0.63	0.78	0.88	0.94

Based upon hydraulic computations for losses in the channel at a flow of 750 cm and low tide level, the total head loss between the Miramar Powerplant afterbay and the Pacific Ocean would be 0.1 m. Therefore, the normal operating afterbay water surfaces at the Miramar Powerplant would be elevation 1.6 maximum and elevation -1.6 minimum. The maximum elevation shown would be a little high since the channel design was based upon low tide elevation and with high tide level the area of flow would be larger and the velocity lower. It is not felt that this would be significant.

c. The Miramar Dam, Spillway, and Powerplant. - The Miramar Dam would be a zoned earth embankment structure built across the Rio Brito. The Tamarindo Powerplant would be constructed at its toe near the western abutment. The intake to the powerplant would be a concrete structure located in the upstream face of the dam embankment and connected to the crest by an operating bridge. The intake structure and the powerplant would be connected by steel penstocks, encased in concrete, and built by cut and cover methods. The spillway would be a concrete crest located on the eastern abutment. The embankment, powerplant, and spillway are shown in figure TT-8. The topography for this layout and profile was produced under contract by ATECASA at a scale of 1:10,000 and a 5-m contour interval. The location of the dam at the Miramar site was dictated by topography and geology and the economic studies of previously discussed alternatives.

No major settlements exist in the reservoir area which would require relocations. Some haciendas and small farms would be affected and require purchase and resettlement. Costs for purchase of lands have been included in the estimate. No problems of land clearing are anticipated although some trees are located within the reservoir area. Most lands are used for agriculture and cattle grazing.

Access to the Miramar damsite would require utilization and improvement of existing roads from the Pan American Highway. The climate of the region should not hinder work except possibly during the 6-month rainy season. Work during this period may be interrupted by the frequent heavy thundershowers which occur sometimes daily but with proper scheduling of the work and good drainage practices, no severe problem is anticipated. Rainfall in the Brito area averages about 1200 mm per year. The year-round heat could be a greater problem, requiring cooling of the mass concrete used in the powerplant and power intake structure.

No facilities for housing of the construction crew are available near the damsite so an extensive construction camp would be required. This could be located near the west abutment and could be utilized in the future if built as a permanent camp. Costs for this camp are included in the estimate.

The foundation exploration at the damsite was located at the present dam and powerplant location and all the holes drilled indicated rock within a few meters of the ground surface. These rocks are all sedimentary sandstones of the Brito Formation. These rocks dip away from the surface as one approaches the ocean. The soils or weathered rock over the foundation of fresh rock were considered adequate to support the embankment so the estimate called for a continuous grout curtain to seal the rock with a slurry trench constructed above it to provide a positive cutoff between the dam core and the underlying rock. It is possible that further studies would recommend extending the core material down the rock. This change will not cause the estimated cost to change greatly since a high allowance for unlisted items and contingencies was added.

No search for construction materials in the Tamarindo area has been made. It is anticipated that material for the embankments would be available from local borrow areas or from channel excavations. Getting the materials to the dam embankment area could be a problem. Concrete fine and coarse aggregates would be a severe problem. Beach sand is available from the Pacific Coast and could be cleaned and shipped from the tailrace channel area. The beach sand would be relatively poorly graded, however, so another source of fine aggregate must be found. The sandstones available locally are unsuitable for concrete aggregate. Some intrusive rock is located northwest of Rivas but its quality and quantity are unknown. The closest source of suitable basalt which could be crushed for aggregate is located in the Cordillera Amerrisque east of

Lake Managua. It would be necessary to set up an aggregate manufacturing plant at the quarry site and then ship the processed aggregate to the construction area. During the feasibility study of the Project, location of borrow areas and the testing of the materials should be done. Type I cement is available from the Canal Cement Company but Type II cement would be imported.

No seismic analysis has been done for the features of the Brito area. If further investigations on this scheme are done, a complete seismic analysis would be required.

The Miramar Powerplant would be located at the downstream toe of Miramar Dam near the western abutment. It would be connected to the concrete intake structure by penstocks of steel encased in concrete. The powerplant designs were based on the system capacity used for studies of the channels. This necessitated powerplant estimates for capacities of 250, 500, 750, and 1000 m^3/s. These estimates allowed construction of the cost curves shown in figure TT-24. The units used for these designs were based on discharge capacity rather than generation capacity. Two units were estimated, one for a design flow of 125 m^3/s and the other for a discharge of 250 cm. Only the 125-cm unit was sized since this information was only required for general site configurations. The maximum and minimum heads on the units would be 34.6 m and 28.6 m, respectively, based upon the water surfaces in the Miramar Reservoir and the powerplant afterbay of the Brito tailrace channel. The design head used in the estimate was based upon preliminary design information and was 30.5 m.

This is less than the average of the maximum and minimum heads so the estimate should be revised for further studies to a design head of 31.6 m. Time did not allow this correction in these studies. Vertical shaft, Francis-type turbines were estimated. Turbine and generator information would be as follows:

Flow capacity	125	cm	250	cm
Horsepower	50 500		101 000	
Synchronous speed	128.6	r/min	94.7	r/min
Specific speed	91.2		95.1	
Generator rating	31.7	MW	63.3	MW
Unit kVA	46 900		93 700	

The Miramar Powerplant would be enclosed and a service and erection bay would be provided. The structure was not dimensioned since no size for the plant was required for the estimate. For the flow capacities estimated, the following units were used:

250 cm - 2 - 125-cm units
500 cm - 4 - 125-cm units
750 cm - 3 - 250-cm units
1000 cm - 4 - 250-cm units

Transformers and a switchyard have been estimated for each plant. It was assumed that one 3-phase transformer would be provided per unit plus one spare transformer. These would be located on a transformer deck on the upstream side of the plant. The switchyard would be located near the present Hacienda Miramar. It was assumed to have one switching bay per unit plus one transfer bay and two outgoing line bays. Transmission lines beyond the switchyard have not been included in the cost estimates made in the memorandum but they have been estimated and are included in the Power Memorandum.

To standardize the estimates, only one penstock was estimated. This was a 10.00-m-diameter steel conduit, 1/4-inch-thick, encased with reinforced concrete. It was assumed that one penstock would service each 250-cm unit. The same penstock would service each two 125-cm units and would bifurcate into two 7.20-m-diameter conduits to reach the unit except for the 250-cm scheme where two 7.2-m penstocks would be used. Downstream guard gates would only be provided with the 125-cm units because of the bifurcation and they would be 7.2-m-diameter butterfly valves. At the upstream end of each penstock would be a wheel-mounted guard gate and a bulkhead gate each 10.9 m high by 7.2 m wide. Only one bulkhead gate would be provided. The penstocks and their encasement would be constructed in cut and cover sections.

The penstock intake structure would be of the drop inlet type with a 12-m-wide separate bay to serve each penstock intake. Each bay would be protected by a steel bar-type trashrack laid over the intake portal. The intake would stay in rectangular section through the penstock intakes and the bulkhead and wheel-mounted guard gates. The intake structure would rise to a service deck above maximum water surface from which the gates would be operated and pulled for maintenance. The service deck would be connected to the dam crest by an operating bridge. A 75-short-ton-capacity gantry crane would be provided on the service deck to move the bulkhead gate and for maintenance of the wheel-mounted gates and trashracks.

The embankment section for the Miramar Dam and the long dike to the north has been estimated as a standard zoned earth section. The crest elevation of these two structures would be at elevation 37.0 giving 1.5 m of freeboard above the maximum reservoir water surface. A crest width of 10.0 m was used with 3:1 upstream slope and 2.5:1 downstream slope. The clay and silt compacted core would rest on weathered rock and a continuous grout curtain would be provided to seal the foundation. A filter would be provided on the downstream face of the core to help drain the section. It was anticipated that slope protection would be provided by a soil cement facing on the upstream face although it may be found that the cut tuff blocks produced in the area may be cheaper. Due to the seismic accelerations, it also may be necessary to provide flatter slopes of waste materials in the deeper dam sections. No analysis has been made and this should be studied during the feasibility study.

The spillway, which would be built on the eastern abutment, would be for emergency use only. It would be a 100-m-wide channel constructed around the dam abutment which would act as a broad crested weir. A grout curtain would be constructed continuous with the dam cutoff and a cap of concrete would form the weir crest to elevation 33.0 With the design storm on the Miramar Reservoir, the reservoir water surface would rise to elevation 35.5. With the reservoir at this maximum water surface elevation, the spillway would discharge 680 m^3/s. A discharge channel would be constructed from the crest to about station 1+000 of the Brito tailrace channel to carry any floodflows away from the dam. This channel would be unlined although it was anticipated that some shotcrete protection may be necessary to stabilize the channel just below the concrete weir.

Diversion for the construction of the dam, powerplant, and spillway should be no problem. The flows of the Rio Brito at the damsite will require diversion during the construction of the embankment. No studies of diversion floods have been done but it is possible that one or two of the power penstocks could be utilized to carry the flows past the embankment. A complete diversion study should be undertaken during the feasibility phase of this project. It is anticipated that some cofferdams will be required with flumes or conduits used to pass the flows. Well points may be required to dry out the foundations of the powerplant and also protections on the downstream side would be required to protect against the tidal encroachment.

Construction Costs

Construction cost estimates presented in this memorandum are based on January 1976; prices and all costs are figures in United States dollars. No breakdown of costs has been made between local and foreign exchanges, only total costs have been figured.

The total costs would be the sum of the local and foreign exchanges. The local exchange portion would be those funds that would be spent locally. This would be on materials, land, and national labor available which would probably be paid by the government involved in the project. Using the results of the San Juan study the local exchange would be about 10 to 15 percent of the total costs. The foreign exchange portion is an estimate of all costs of foreign materials, equipment, and labor which are not available locally and it is anticipated that this portion would be the amount internationally financed. No local taxes or duties have been added to any of the costs estimated. Financing charges for interest during construction were added to the total costs (see the Economics Memorandum).

Because the study is at the prefeasibility level, the estimates are at an intermediate level between feasibility and reconnaissance grades. Wherever possible, depending upon the information and the allotted time available, the attempt was made to use feasibility methods in the design and estimates. In some cases for some items, reconnaissance methods were used although every effort was made to ensure that such estimates would conform as closely as possible to known site conditions and operating limitations. The estimated field cost, which consists of estimated contract earnings, rights of way, and relocation was developed. The field cost included a lump sum amount to cover unlisted items not usually included in a prefeasibility quality estimate, and a lump sum amount to cover contingencies. Service facilities are also included in the field cost as a contract earning. The costs of investigation, engineering, supervision, and general expense have been added to the field cost to develop the total project cost. Costs of interest during construction and annual operating and maintenance costs have been added in the economic analysis and are discussed in the Economics Memorandum.

A complete cost estimate was prepared for each scheme according to the following diversion capacities:

Scheme	Diversion Capacity (cm)
Tipitapa plus San Isidro Dam	500, 1000, 1500
Tamarindo	250, 500, 750, 1000
Brito plus San Isidro Dam	250, 500, 750, 1000

To indicate the method of estimating and the prices and quantities used, a sample estimate for each scheme is enclosed. The table TT-2 is the cost estimate for the 500-cm-capacity Tipitapa Scheme plus San Isidro Dam. Table TT-3 is the cost estimate for the 750-cm-capacity Tamarindo Scheme without San Isidro Dam. Table TT-4 is the cost estimate for the 750-cm-capacity Brito Scheme plus San Isidro Dam.

From the cost estimates, a cost summary was prepared (see table TT-5) and cost curves were prepared for each scheme to allow the determination of construction costs for any scheme capacity desired. These are shown in figures TT-22, 23, and 24.

Unit Costs

The unit costs used in these estimates are based upon the studies of the Rio San Juan (see appendix E of the Rio San Juan Project). The costs have been modified from those estimated for the San Juan dams to reflect the more moderate construction locations, climate, and size of project.

Allowance for Unlisted Items

Depending upon the detail used in estimating each feature an allowance to cover the cost of items not included in the estimate was added. This varied from 10 to 20 percent of the subtotaled cost. The more complete estimates used, the smaller allowance; most items had an allowance of 10 or 15 percent.

Contingencies

A lump sum item was added to the subtotal cost to determine the field cost. This varied between 10 to 30 percent of the subtotaled cost including unlisted items. This percentage was added to allow for geologic unknowns, topographic variables, and problems involved in borrowing materials. It should be noted that no material testing was done for this project, borrow areas have not been located, waste disposal areas have not been located, and no diversion floods have been routed.

Investigations, Engineering, Supervision, and General Expenses

This item, 18 percent of the field cost, includes all costs for further studies, surveys, designs and specifications, construction engineering, supervision, and general expenses. This would be applied to both local and foreign exchange field cost. Investigation cost would include the cost of this study plus any further studies and the continuation of collecting and analyzing hydrologic data, additional geologic investigation, material exploration and testing, and detailed survey work and topographic mapping at the construction sites and throughout the reservoir areas. Engineering cost would cover the preparation of designs, construction drawings, and specifications. Supervision cost would cover the engineering administration, supervision, and control of construction. General expenses would include general office salaries and expenses, rental and utility cost, and general transportation expenses for other than contractor personnel.

These costs would include all further studies such as feasibility or preconstruction reports all the way through the construction of the project. They would include all costs attributable to the project by the government plus the lending agency.

Construction Cost Summary and Cost Curves

Table TT-5 shows the cost summary for all the schemes. These costs include the field costs plus the cost of investigation, engineering, supervision, and general expenses. The costs have been broken down to allow the construction of cost curves to which a plant factor different than the scheme capacity can be applied. Therefore, the generating or pumping equipment is shown separately from all other features so spare units can be added or so the size of the pumping plant or powerplant can have a different capacity than the rest of the system.

The cost curves are as follows:

Figure TT-22	Tipitapa Scheme plus San Isidro Dam
Figure TT-23	Tamarindo Scheme
Figure TT-24	Brito Scheme plus San Isidro Dam

To use these curves, the system diversion capacity should be known and also the desired capacity of the pumping or generating plants. The costs of both items would then add together to get the total project cost. The costs shown are the field costs plus the cost of investigations, engineering, supervision, and general expenses. Transmission lines and interest during construction are not included.

Construction Schedule

To aid in the economic analysis of the Tipitapa-Tamarindo Scheme as well as the Brito alternative, a very tentative construction schedule is shown in table TT-6. This indicates the annual progress which would be possible on each scheme if no unusual delays occurred and also the annual schedule of project cost appropriations. The final dates of July 1984 for the Tipitapa-Tamarindo Scheme and July 1983 for the Brito Scheme obviously depend upon the emphasis placed on project completion and the availability of construction money.

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Table TT-1. - Features of project reservoirs

Pool	Elevation top of pool (meters)	Pool area (hectares)	Pool capacity (millions of cubic meters)	Remarks
Lake Nicaragua				
Inactive	31.7	816 000	Unknown	
Active	32.5		Average	
Conservation	33.0	881 500	31 240	
Surcharge	33.6	912 000	5 375	Results of flood routing over weir at San Isidro
Lake Managua				
Inactive	38.5	102 500	9 386	
Active				Lake level controlled by pumping and generating operations
Conservation	38.5	102 500	9 386	
Surcharge	39.6	107 000	1 266	Results of flood routing over El Libano spillway
Tamarindo Reservoir				
Inactive	37.2	1 700	93.6	Established by system hydraulic study - Q = 750 cm
Active				
Conservation	38.5	1 950	23.0	Level of Lake Managua
Surcharge	41.5	2 580	71.8	Results of flood routing with dike fuse plug spillway
Miramar Reservoir				
Inactive	30.2	1 130	99.5	Established by system hydraulic study - Q = 750 cm
Active				
Conservation	33.0	1 265	33.6	Level of Lake Nicaragua
Surcharge	35.5	1 420	36.0	Results of flood routing over Miramar spillway

CONSTRUCTION COSTS - TIPITAPA SCHEME (500 cms.)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-2
(PAGE 1 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10³) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
SAN ISIDRO DAM							
Excavation for Dam	c.m.	19,000	2.20				41,800
Place Earthen Cofferdams	c.m.	111,180	6.50				722,600
Remove Earthen Cofferdams	c.m.	100,000	1.50				150,000
Grouting and Drainage	l.s.	l.s.	l.s.				600,000
Concrete	c.m.	12,120	100.00				1,212,000
Cement	sks.	65,600	3.00				196,800
Abutment Embankment Core	c.m.	600	8.00				4,800
Rock for Abutment Embankment, Riprap and Gravel Blankets	c.m.	5,400	12.00				64,800
Diversion and Care of the River	l.s.	l.s.	l.s.				500,000
Allowance for Unlisted Items (15%+)	l.s.	l.s.	l.s.				507,200
Subtotals							4,000,000
Contingencies (20%+)							800,000
Field Costs							4,800,000

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CONSTRUCTION COSTS - TIPITAPA SCHEME (500 cms).
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-2
(PAGE 2 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($\$x10^3$) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
TIPITAPA ENTRANCE CHANNEL							
Excavation - Common - for Channels	c.m.	18,800,000	1.00				18,800,000
Excavation - Rock - for Channels	c.m.	700,000	4.00				2,800,000
Excavation - Unclassified - for Structures	c.m.	12,000	5.00				60,000
Fill in Channel Banks	c.m.	1,000,000	2.00				2,000,000
Extra Fill en Channel Banks at Structures	c.m.	45,000	4.00				180,000
Rockfill in Jetty	c.m.	200,000	6.00				1,200,000
Protective Rock Blanket at Structures	c.m.	8,000	10.00				80,000
Concrete in Structures	c.m.	3,180	100.00				318,000
Cement	sks.	23,000	2.50				57,500
Reinforcement	kg.	191,000	0.40				76,400
Construct the following Bridges - supported on timber piles:							
Sta. 0 + 740	s.m.	1,200	400.00				480,000
Sta. 21+300	s.m.	1,500	400.00				600,000
Allowance for Unlisted Items (10%+)	l.s.	l.s.	l.s.				2,648,100
Subtotals							29,300,000
Contingencies (20%+)							5,900,000
Field Costs							35,200,000

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CONSTRUCTION COSTS - TIPITAPA SCHEME (500 cms)
PLUS SAN ISIDRO DAM

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TABLE TT-2
(PAGE 3 of 5)

COST ITEM	Unit	Quantity	Unit Cost (\$) Dollars		Total Cost (\$x10^{3}) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
LIBANO DAM AND PUMPING PLANT							
SPILLWAY							
EXCAVATION - Common - for Weir and Channels	c.m.	560,000	1.50				840,000
Excavation - Rock - for Weir	c.m.	10,000	6.00				60,000
Concrete in Weir	c.m.	24,000	80.00				1,920,000
Cement	sks.	173,000	2.50				432,500
Allowance for Unlisted Items (15%+)	l.s.	l.s.	l.s.				447,500
subtotals							3,700,000
Contigencies (20%+)							800,000
Field Costs							4,500,000
DAM ABUTMENTS - INCLUDES RETAINING WALLS, RDWY RELOCATION AND GROUTING/DRAINAGE FOR DAM, SPILLWAY AND PUMPING PLANT							
Excavation - Common	c.m.	150,000	1.60				240,000
Place Embankments as follow:							
Zone 1 - Impervoius Core	c.m.	140,000	1.80				252,000
Zones 2 and 3 - Selected Rockfill and sand	c.m.	80,000	2.30				184,000
Concrete in Walls	c.m.	5,000	120.00				600,000
Cement (except grouting)	sks.	36,000	2.50				90,000
Reinforcement	kg.	100,000	0.40				40,000
Grouting and Drainage - Complete Structure	l.s.	l.s.	l.s.				500,000
Diversion and Care of Foundations - Complete Structure	l.s.	l.s.	l.s.				200,000
Allowance for Unlisted Items (15%+)							294,000
Subtotals							2,400,000
Contingencies (25%+)							600,000
Field Costs							3,000,000

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CONSTRUCTION COSTS - TIPITAPA SCHEME (500 cms.)
PLUS SAN ISIDRO DAM

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TABLE TT-2
(PAGE 4 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10³) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
LIBANO DAM AND PUMPING PLANT (Cont.)							
PUMPING PLANT AND SWITCHYARD							
Recon. Grade Estimate using Estimating Data Appendix A prices, indexed to Jan. 1976							
Pumping Plant and Switchyard Complete 8 - 62.5 cms. units Subtotal	l.s.	l.s.	l.s.				66,800,000
Contingencies (10%±)							6,700,000
Field Costs							73,500,000
PUMPING PLANT WATERWAYS							
Include Extra Costs for Intake and Outlet Siphons							
Excavation - Common	c.m.	100,000	1.60				160,000
Excavation - Rock	c.m.	12,000	6.00				72,000
Concrete	c.m.	40,000	100.00				4,000,000
Cement	sks.	290,000	2.50				725,000
Reinforcement	kg.	800,000	0.40				320,000
Bulkhead Gates - 2ea movable	kg.	16,000	5.00				80,000
Bulkhead Frames and Guides	kg.	20,000	7.00				140,000
Gantry Crane 15 Short Ton Capacity	l.s.	l.s.	l.s.				75,000
Trashracks	kg.	26,000	3.00				78,000
Allowance for Unlisted Items (10%+)	l.s.	l.s.	l.s.				550,000
Subtotals							6,200,000
Contingencies (20%+)							1,300,000
Field Costs							7,500,000

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CONSTRUCTION COSTS - TIPITAPA SCHEME (500 cms.)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-2
(PAGE 5 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10^3) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
TIPITAPA PUMP OUTLET CHANNEL							
Excavation - Common - for Channels	c.m.	960,000	1.30				1,248,000
Excavation - Rock - for Channels	c.m.	1,430,000	3.00				4,290,000
Excavation - Unclassified - for Structures	c.m.	17,300	5.00				86,500
Fill in Channel Banks	c.m.	450,000	2.00				900,000
Extra Fill in Channel Banks at Structures	c.m.	108,000	4.00				432,000
Protective Rock Blanket at Structures	c.m.	6,200	10.00				62,000
Concrete in Structures	c.m.	7,620	100.00				762,000
Concrete in Lining	c.m.	20,600	90.00				1,854,000
Refill under Lining	c.m.	41,000	5.00				205,000
Trimming Rock under Lining	s.m.	275,000	2.00				550,000
Cement	sks.	203,000	2.50				507,500
Reinforcement	kg.	457,000	0.40				182,800
Construct the following Bridges:							
Sta. 0 + 440	s.m.	610	500.00				305,000
Sta. 3+730 - Pan American Highway Crossing with Stoplogs	s.m.	780	750.00				585,000
Allowance for Unlisted Items (10%±)							1,230,200
Subtotals							13,200,000
Contigencies (20%±)							2,600,000
Field Costs							15,800,000
PROJECT LANDS	hectare	610	200.00				122,000
PROJECT CAMP	l.s.	l.s.	l.s.				1,378,000
Field Costs							1,500,000

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CONSTRUCTION COSTS - TAMARINDO SCHEME (750 cms)
SAN ISIDRO DAM NOT INCLUDED

JUNE 1977

TABLE TT-3
(PAGE 1 of 4)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10³) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
TAMARINDO ENTRANCE CHANNEL (CEIBA MOCHA CUT)							
Excavation - Common - for Channels	c.m.	6,510,000	1.30				8,463,000
Excavation - Rock - for Channels	c.m.	5,340,000	3.00				16,020,000
Excavation - Unclassified - for Structures	c.m.	37,000	5.00				185,000
Fill in Channel Banks	c.m.	1,200,000	2.00				2,400,000
Extra Fill in Channel Banks at Structures	c.m.	173,000	4.00				692,000
Rockfill in Jetty	c.m.	70,000	6.00				420,000
Protective Rock Blanket at Structures	c.m.	20,400	10.00				204,000
Concrete in Structures	c.m.	14,040	100.00				1,404,000
Concrete in Lining	c.m.	370,000	90.00				3,330,000
Refill under Lining	c.m.	74,000	5.00				370,000
Trimming Rock under Lining	s.m.	494,000	2.00				988,000
Cement	sks.	365,000	2.50				921,500
Reinforcement	kg.	846,000	0.40				338,400
Construct the following Bridges							
León Highway 2+130 (includes stoplogs)	s.m.	732	750.00				549,000
Sta. 2+500 (Railroad Bridge)	l.m.	33	3,000.00				99,000
Sta. 7+230 Railroad Bridge	l.m.	33	3,000.00				99,000
San Gabriel to Casa Blanca 8+250	s.m.	1,280	500.00				640,000
Allowance for Unlisted Items (10%±)	l.s.	l.s.	l.s.				3,685,900
Subtotals							40,800,000
Contingencies (20%±)							8,200,000
Field Costs							49,000,000

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CONSTRUCTION COSTS - TAMARINDO SCHEME (750 cms)
SAN ISIDRO DAM NOT INCLUDED

JUNE 1977

TABLE TT-3
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COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($\$\times 10^3$) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
TAMARINDO ENTRANCE CHANNEL (Cont.)							
RAILROAD RELOCATION							
Total Single track relocation	km.	10.3	45,000.00				463,500
Construct complete railroad bridges	lm.	60	6,000.00				360,000
Place culverts	ea.	12	4,000.00				48,000
Subtotals							871,500
Contingencies (25%±)							228,500
Field Costs							1,100,000
DIKES							
Excavate for dikes	cm.	430,000	1.25				537,500
Place embankments as follow:							
Zone 1 - Impervious Core	cm.	260,000	1.50				390,000
Zone 2 - Selected rockfill and sand	cm.	120,000	2.50				300,000
Zone 3 - Selected rockfill and sand	cm.	120,000	1.40				168,000
Diversion and Care of Foundations	l.s.	l.s.	l.s.				50,000
Allowance for Unlisted Items (20%±)	l.s.	l.s.	l.s.				254,500
Subtotals							1,700,000
Contigencies (30%±)							600,000
Field Costs							2,300,000
SPILLWAY							
Estimate made for Fuse Plug Spillway - Modifications to Dike							
Field Costs	l.s.	l.s.	l.s.				1,000,000

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CONSTRUCTION COSTS - TAMARINDO SCHEME (750 cms)
SAN ISIDRO DAM NOT INCLUDED

JUNE 1977

TABLE TT-3
(PAGE 3 of 4)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10³) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
TAMARINDO DAM AND POWERPLANT							
TAMARINDO DAM							
Excavate for Dam	c.m.	1,440,000	1.30				1,872,000
Drill for Grout Curtain	l.m.	25,000	20.00				500,000
Place embankments as follow:							
Zone 1 - Impervious Core	c.m.	3,500,000	1.50				5,325,000
Zone 2 - Selected rockfill and sand	c.m.	1,960,000	2.50				4,900,000
Zone 3 - Slected rockfill and sand	c.m.	1,790,000	1.40				2,506,000
Zone 4 - Filter material	c.m.	200,000	3.00				600,000
Place Wearing Surface on Dam	c.m.	12,000	8.50				102,000
Relocate León Highway	l.m.	1,700	100.00				170,000
Pressure Grouting Foundation	sks.	85,000	5.00				425,000
Cement in Grout Curtain	sks.	85,000	2.50				212,500
Diversion and Care of Foundations	l.s.	l.s.	l.s.				300,000
Allowance for Unlisted Items (20%)	l.s.	l.s.	l.s.				3,387,500
Subtotals							20,300,000
Contingencies (25%+)							5,100,000
Field Costs							25,400,000
TAMARINDO TAILRACE CHANNEL							
Excavation - Common	c.m.	17,360,000	1.10				19,096,000
Rockfill in Jetty	c.m.	240,000	6.00				1,440,000
Allowance for Unlisted Items (10%+)	l.s.	l.s.	l.s.				2,064,000
Subtotals							22,600,000
Contingencies (15%+)							3,400,000
Field Costs							26,000,000
PROJECT LANDS	hectare	1,530	200.00				306,000
PROJECT CAMP	l.s.	l.s.	l.s.				1,694,000
Field Costs							2,000,000

JANUARY, 1976 PRICES

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CONSTRUCTION COSTS - TAMARINDO SCHEME (750 cms)
SAN ISIDRO DAM NOT INCLUDED

JUNE 1977

TABLE TT-3
(PAGE 4 of 4)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($\$x10^3$) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
TAMARINDO DAM AND POWERPLANT (Cont)							
POWERPLANT AND SWITCHYARD							
Recon. Grade Estimate using Estimating Data Appendix A prices, indexed to Jan. 1976							
Powerplant and Switchyard Complete							
3 - 250 cms. Units Subtotal	l.s.	l.s.	l.s.				81,000,000
Contingencies (10%±)							8,100,000
Field Costs							89,100,000
PENSTOCK AND POWER INTAKES							
3 - 8.75 M Penstocks							
Excavation - Common	c.m.	240,000	1.60				348,000
Excavation - Rock	c.m.	57,000	6.00				342,000
Specially Placed Core Material Backfill	c.m.	215,000	5.00				1,075,000
Concrete in structures	c.m.	29,450	100.00				2,945,000
Cement	sks.	213,000	2.50				532,500
Reinforcement	kg.	2,490,000	0.40				996,000
Bridges to Intake	s.m.	560	250.00				140,000
Gantry Crane 75 short-ton Capacity	l.s.	l.s.	l.s.				160,000
Steel Pipe	kg.	3,284,000	1.10				3,612,400
Bulkhead and Wheel-Mounted Gates	kg.	361,000	5.00				1,805,000
Gate Frames, Guides and Hoists	kg.	240,000	7.00				1,680,000
Trashracks	kg.	21,000	3.00				63,000
Allowance for Unlisted Items (10%±)	l.s.	l.s.	l.s.				1,365,100
Subtotals							15,100,000
Contigencies (15%±)							2,300,000
Field Costs							17,400,000

JANUARY, 1976 PRICES

CONSTRUCTION COSTS - BRITO SCHEME (750 cms)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-4
(PAGE 1 Of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10³) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
SAN ISIDRO DAM							
Excavation for Dam	c.m.	19,000	2.20				41,800
Place Earthen Cofferdams	c.m.	111,180	6.50				722,600
Remove Earthen Cofferdams	c.m.	100,000	1.50				150,000
Grouting and Drainage	l.s.	l.s.	l.s.				600,000
Concrete	c.m.	12,120	100.00				1,212,000
Cement	sks.	65,600	3.00				196,800
Abutment Embankment Care	c.m.	600	8.00				4,800
Rock for Abutment Embankment, Riprap and Gravel Balnkets	c.m.	5,400	12.00				64,800
Diversion and Care of the River	l.s.	l.s.	l.s.				500,000
Allowance for Unlisted Items (15%±)	l.s.	l.s.	l.s.				507,200
Subtotals							4,000,000
Contigencies (20%±)							800,000
Field Costs							4,800,000

JANUARY, 1976 PRICES

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CONSTRUCTION COSTS - BRITO SCHEME (750 cms)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-4
(PAGE 2 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($x10³) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
BRITO ENTRANCE CHANNEL							
Excavation - Common - for Channels	c.m.	12,170,000	1.30				15,821,000
Excavation - Rock - for Channels	c.m.	11,150,000	2.00				22,300,000
Excavation - Unclassified - for Structures	c.m.	56,000	5.00				280,000
Fill in Channel Banks	c.m.	960,000	2.00				1,920,000
Extra Fill in Channel Banks at Structures	c.m.	335,000	4.00				1,340,000
Rockfill in Jetty	c.m.	160,000	6.00				960,000
Protective Rock Blanket at Structures	c.m.	25,700	10.00				257,000
Concrete in Structures	c.m.	22,910	100.00				2,291,000
Concrete in Lining	c.m.	56,900	90.00				5,121,000
Refill under Lining	c.m.	114,000	5.00				570,000
Trimming Rock under Lining	s.m.	759,000	2.00				1,518,000
Cement	sks.	575,100	2.50				1,437,750
Reinforcement	kg.	1,387,000	0.40				554,800
Construct the Following Bridges:							
Hwy #2 @ Sta. 1 + 040	s.m.	1,560	600.00				936,000
Sta. 4 + 030 (includes stoplogs)	s.m.	670	750.00				502,500
Sta. 10 + 280	s.m.	690	500.00				345,000
Allowance for Unlisted Items (10%+)	l.s.	l.s.	l.s.				5,645,950
Subtotals							61,800,000
Contingencies (20%±)							12,400,000
Field Costs							74,200,000

JANUARY, 1976 PRICES

CONSTRUCTION COSTS - BRITO SCHEME (750 cms)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-4
(PAGE 3 of 5)

COST ITEM	Unit	Quantity	Unit Cost (\$) Dollars		Total Cost (\$x10^3) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
MIRAMAR DAM AND POWERPLANT							
Excavate for dam - Common	c.m.	140,000	1.25				175,000
Place embankments as follow:							
Zone 1 - Impervious Core	c.m.	1,400,000	1.50				2,100,000
Zone 2 - Selected sand, silt, etc.	c.m.	700,000	1.40				980,000
Zone 3 - Selected sand, silt, etc.	c.m.	600,000	1.40				840,000
Zone 4 - Filter Material	c.m.	400,000	3.00				1,200,000
Construct Soil Cement Facing	c.m.	85,000	13.00				1,105,000
Place Wearing Surface on Dam	c.m.	6,000	8.50				51,000
Construct Slurry Trench Cutoff - includes exc. and all materials	c.m.	50,000	40.00				2,000,000
Drill for Grout Curtain	l.m.	13,000	20.00				260,000
Cement Soil Cement and Grout Curtain	sks.	425,000	2.50				1,062,500
Pressure Grouting Foundation - Grout Curtain	sks.	25,000	5.00				125,000
Diversion and Care of Foundations	l.s.	l.s.	l.s.				100,000
Allowance for Unlisted Items (20%±)							2,001,500
Subtotals							12,000,000
Contingencies (25%±)							3,000,000
Field Costs							15,000,000
POWERPLANT AND SWITCHYARD							
Recon. Grade Estimate using Estimation Data Appendix A prices, indexed to Jan. 1976							
Powerplant and Switchyard Complete							
3 - 250 cms. Units Subtotals	l.s.	l.s.	l.s.				81,812,000
Contingencies (10%±)							8,188,000
Field Costs							90,000,000

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CONSTRUCTION COSTS - BRITO SCHEME (750 cms.)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-4
(PAGE 4 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost (x10^3$) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
MIRAMAR DAM AND POWERPLANT (Cont.)							
PENSTOCKS AND POWER INTAKES							
3-250 cms. Units with 3-10.0 m Penstocks							
Excavation - Common	c.m.	221,000	1.60				353,600
Excavation - Rock	c.m.	35,000	6.00				210,000
Specially Placed Core Material Backfill	c.m.	174,000	5.00				870,000
Concrete in Structures	c.m.	29,700	100.00				2,970,000
Cement	sks.	215,000	2.50				537,500
Reinforcement	kg.	2,524,000	0.40				1,009,600
Steel Pipe	kg.	3,811,000	1.10				4,192,100
Bulkhead and Wheel-mounted gates	kg.	389,000	5.00				1,945,000
Gate Frames, Guides and Hoists	kg.	234,000	7.00				1,638,000
Trashracks	kg.	21,000	3.00				63,000
Bridges to Intake	s.m.	320	200.00				64,000
Gantry Crane 75 Short Ton Capacity	l.s.	l.s.	l.s.				160,000
Allowance for Unlisted Items (10%+)							1,387,200
Subtotals							15,400,000
Contingencies (15%+)							2,300,000
Field Costs							17,700,000

JANUARY, 1976 PRICES

CONSTRUCTION COSTS - BRITO SCHEME (750 cms.)
PLUS SAN ISIDRO DAM

JUNE 1977

TABLE TT-4
(PAGE 5 of 5)

COST ITEM	Unit	Quantity	Unit Cost ($) Dollars		Total Cost ($\$x10^3$) (Thousand of Dollars)		
			Foreign	Local	Foreign	Local	Total
MIRAMAR DAM AND POWERPLANT (Cont.)							
SPILLWAY							
Excavation - Common	c.m.	150,000	1.60				240,000
Excavation - Rock	c.m.	550,000	4.00				2,200,000
Drilling Grout and Drainage Holes	l.m.	3,500	40.00				140,000
Pressure Grouting Foundation	sks.	8,600	5.00				43,000
Concrete in Grout Cap and Crest.	c.m.	1,250	150.00				187,500
Shotcrete on Crest	c.m.	600	150.00				90,000
Cement	sks.	23,000	2.50				57,500
Allowance for Unlisted Items (10%±)	l.s.	l.s.	l.s.				342,000
Subtotals							3,300,000
Contigencies (20%±)							700,000
Field Costs							4,000,000
BRITO TAILRACE CHANNEL							
Excavation - Common - for Tailrace	c.m.	15,550,000	1.10				17,105,000
Rockfill in Jetty	c.m.	240,000	6.00				1,440,000
Allowance for Unlisted Items (10%+)							1,855,000
Subtotals							20,400,000
Contigencies (15%+)							3,100,000
Field Costs							23,500,000
PROJECT LANDS	Hectare	1,500	200.00				300,000
PROJECT CAMPS	l.s.	l.s.	l.s.				2,200,000
Field Costs							2,500,000

JANUARY, 1976 PRICES

TABLE TT-5

COST SUMMARY

FIELD COSTS PLUS 18% INVESTIGATION, ENGINEERING AND SUPERVISION

TIPITAPA SCHEME PLUS SAN ISIDRO DAM	TOTAL COST (Millions of Dollars)* Flow Capacity - cms.			
		500	1,000	1,500
Pumping Plant and Pumping Plant Water ways		$ 95.6	$177.9	$246.1
All Other Costs - Dams, channels, Spillway, etc.*		$ 76.5	$ 97.7	$120.9
TAMARINDO SCHEME				
	250	500	750	1,000
Powerplant and Powerplant Waterways	$ 53.1	$ 94.0	$125.7	$155.2
All Other Costs - Dam, Dikes, Channels, Spillway, etc.*	$ 95.4	$109.6	$126.0	$141.6
BRITO SCHEME PLUS SAN ISIDRO DAM	250	500	750	1,000
Powerplant and Powerplant Waterways	$ 54.8	$ 95.7	$127.1	$154.0
All Other Costs - Dams, Channels, Spillway, etc.*	$112.5	$128.1	$146.3	$163.4

*Costs do not include transmission lines or interest during construction

All Costs January 1976 level.

TABLE TT-6

CONSTRUCTION SCHEDULE

TIPITAPA-TAMARINDO AND BRITO SCHEMES
SAN ISIDRO DAM INCLUDED

PRELIMINARY DATA

Finish Prefeasibility Study	July, 1977
Finish Feasibility Study	July, 1978
Advertise for Bids	July, 1979
Begin Construction	January, 1980
Units on Line	
Tipitapa Tamarindo	July, 1984
Brito	July, 1983

CONSTRUCTION COST BREAKDOWN

	CONSTRUCTION YEAR				
	1980	1981	1982	1983	1984
SCHEME	PERCENT OF CONSTRUCTION COMPLETED				
Tipitapa-Tamarindo	20	20	25	25	10
Brito	20	30	35	15	

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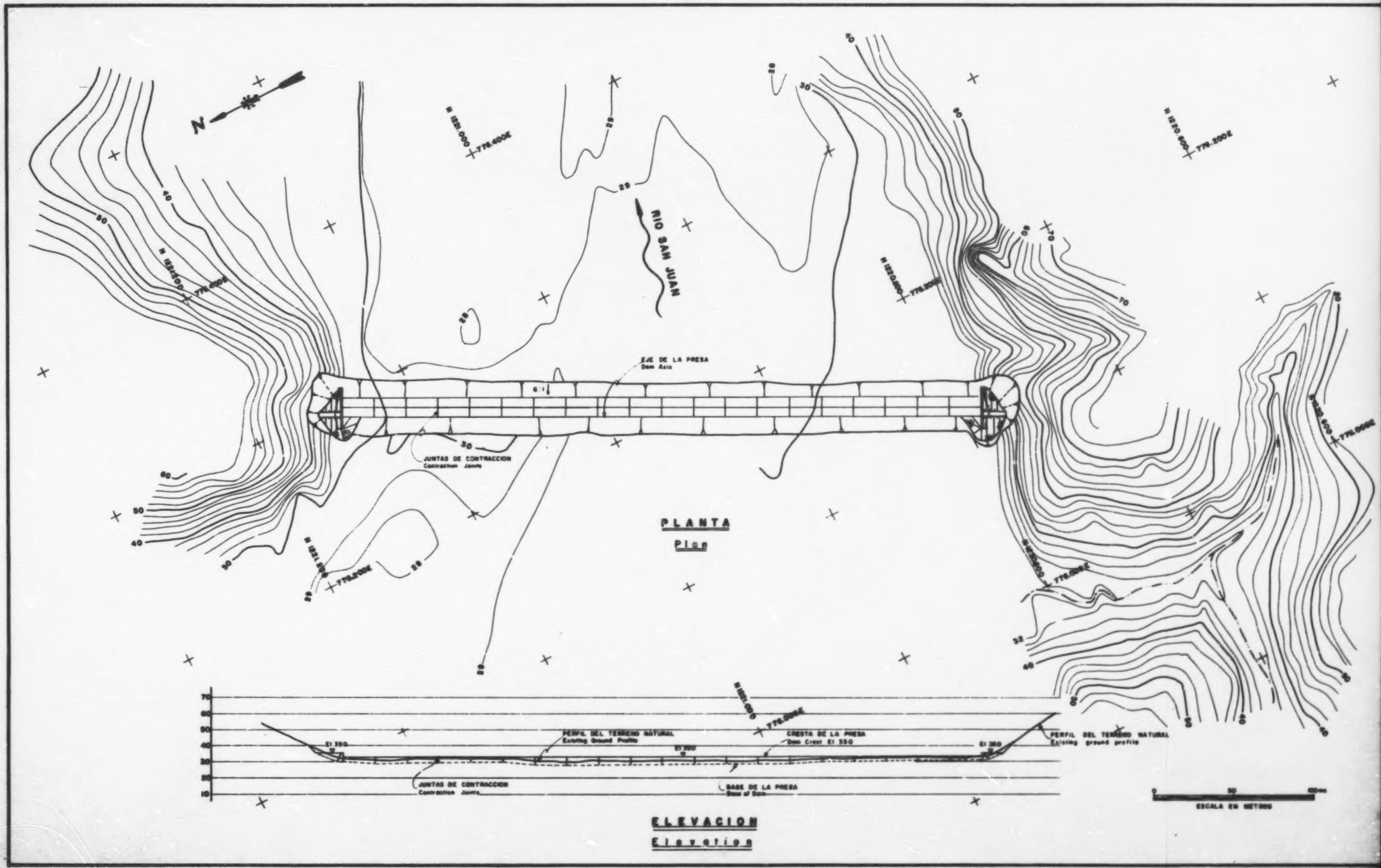
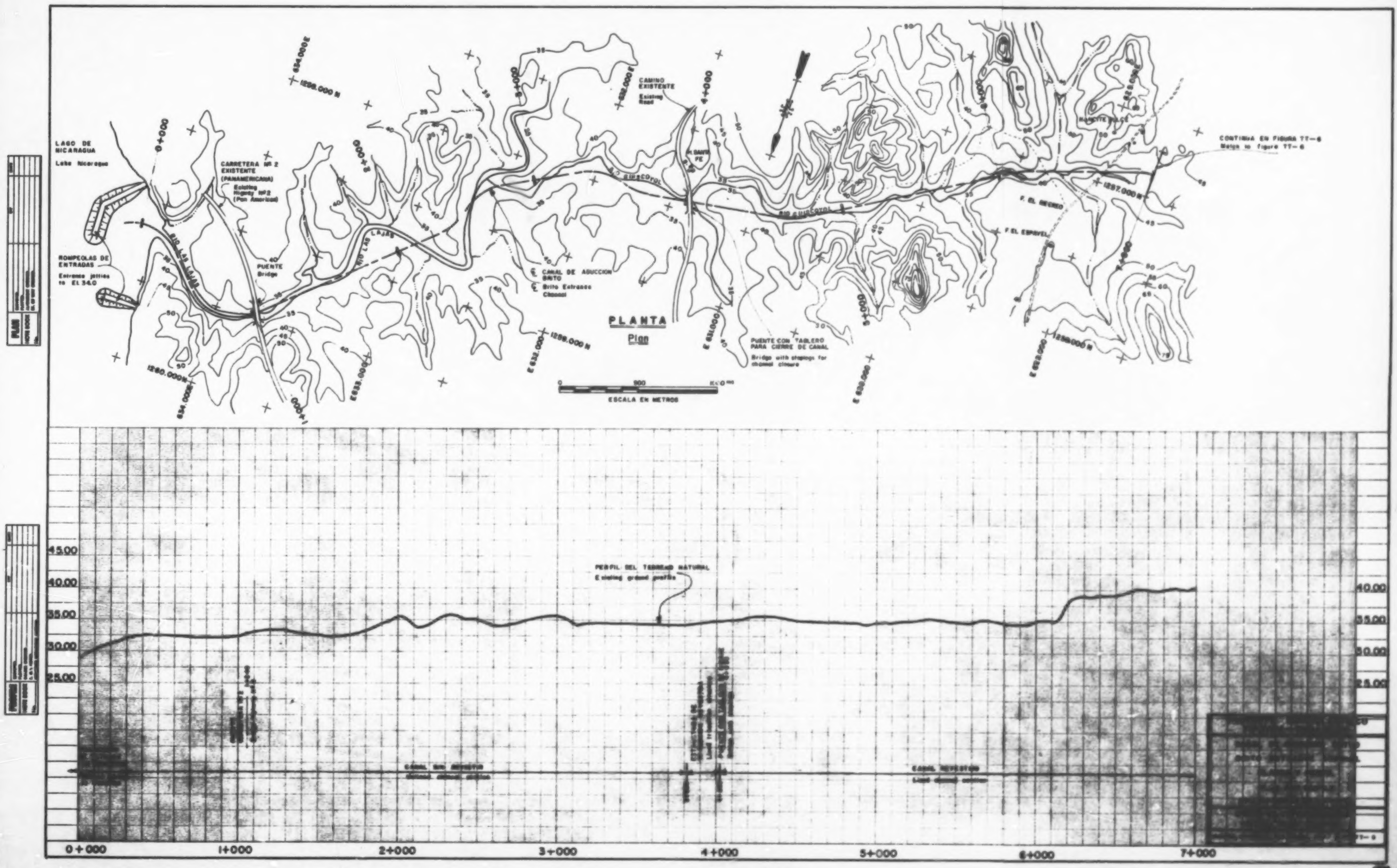
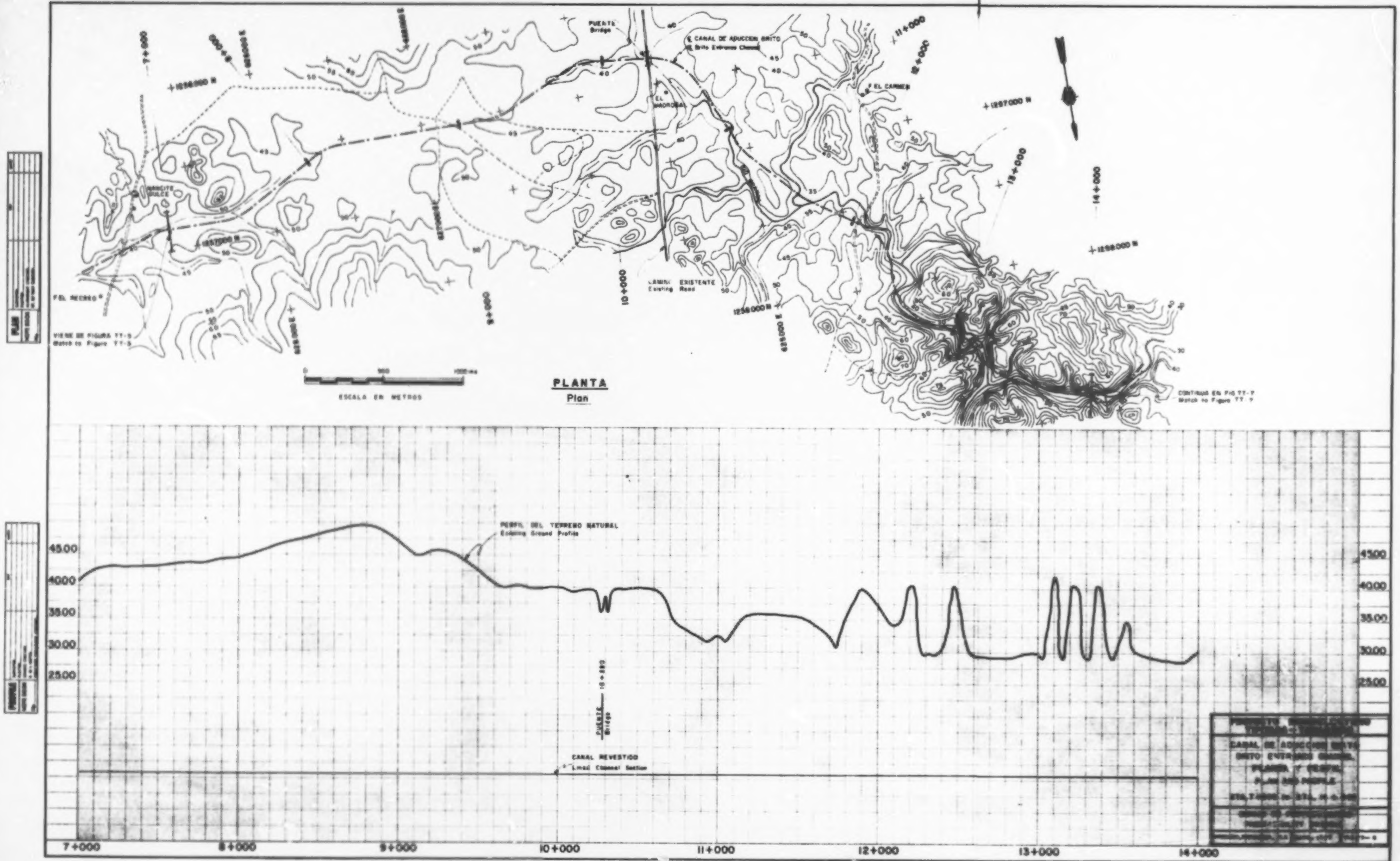
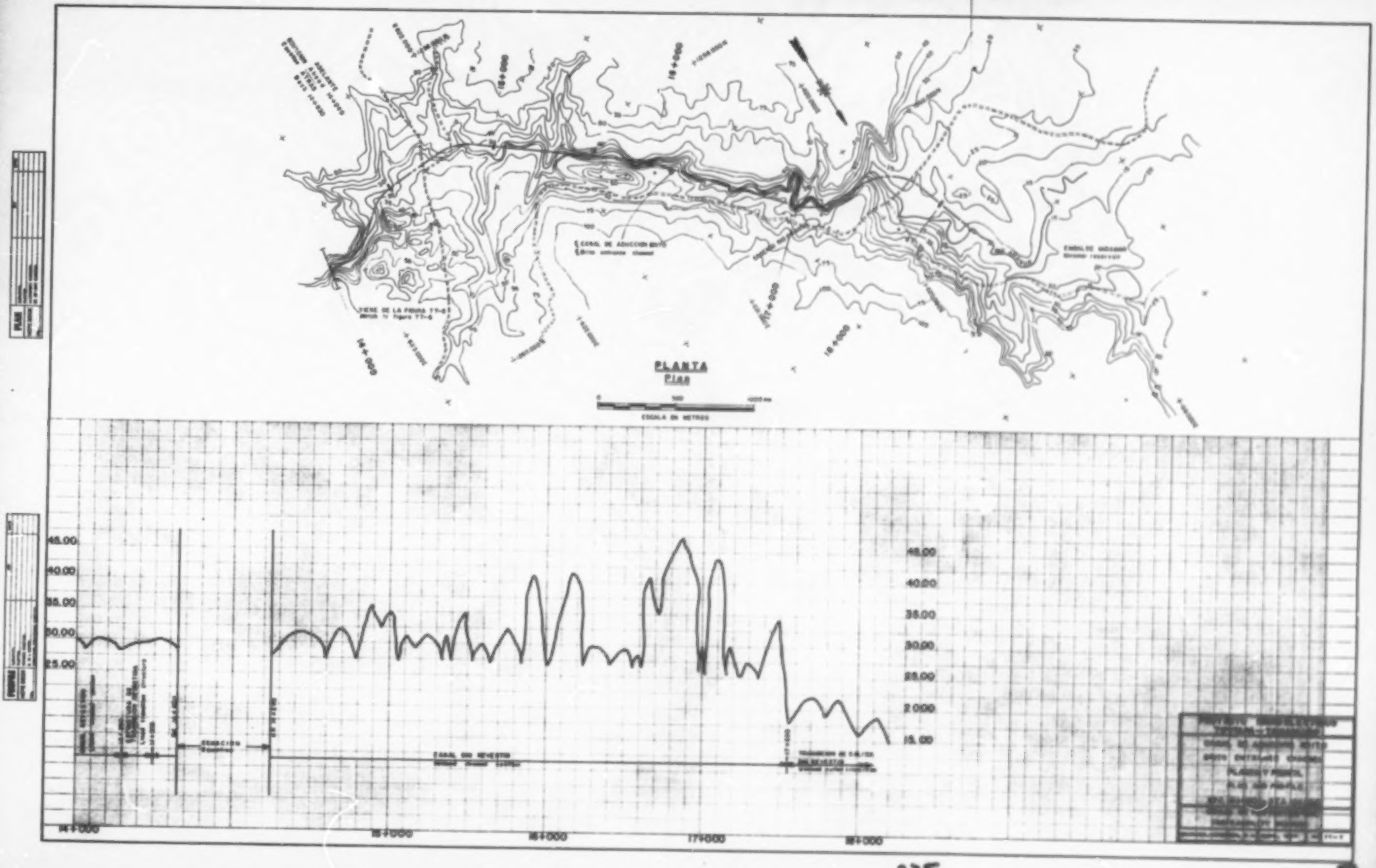

N
RIO SAN JUAN
EJE DE LA PRESA
Dam Axis
JUNTAS DE CONTRACCION
Contraction Joints
PLANTA
Plan
70
60
50
40
30
20
10
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
CRESTA DE LA PRESA
Dam Crest El 330
El 330
JUNTAS DE CONTRACCION
Contraction Joints
BASE DE LA PRESA
Base of Dam
PERFIL DEL TERRENO NATURAL
Existing ground profile
ELEVACION
Elevation
0
50
100
ESCALA EN METROS


LAGO DE NICARAGUA
Lake Nicaragua
ROMPEOLAS DE ENTRADAS
Entrance jetties to EL 34.0
CARRETERA Nº 2 EXISTENTE (PANAMERICANA)
Existing Highway Nº 2 (Pan American)
PUENTE
Bridge
RIO LAS LAJAS
RIO GUISCOYOL
℄ CANAL DE ADUCCION BRITO
℄ Brito Entrance Channel
CAMINO EXISTENTE
Existing Road
PUENTE CON TABLERO PARA CIERRE DE CANAL
Bridge with staplogs for channel closure
F. EL RECREO
F. EL ESPAVEL
CONTINUA EN FIGURA TT-6
Match to figure TT-6
PLANTA
Plan
ESCALA EN METROS
0
900
0+000
1+000
2+000
3+000
4+000
5+000
6+000
7+000
1260.000 N
1259.000 N
1258.000 N
1257.000 N
634.000 E
633.000 E
632.000 E
631.000 E
630.000 E
629.000 E
PERFIL DEL TERRENO NATURAL
Existing ground profile
CANAL SIN REVESTIR
CANAL REVESTIDO
45.00
40.00
35.00
30.00
25.00
TT-5


PUENTE
Bridge
℄ CANAL DE ADUCCION BRITO
℄ Brito Entrance Channel
EL MADROÑAL
F EL CARMEN
F EL RECREO
GRACITE DULCE
CAMINO EXISTENTE
Existing Road
+1256000 N
+1257000 N
+1258000 N
+1257000 N
+1258000 N
1256000 N
7+000
8+000
9+000
10+000
11+000
12+000
13+000
14+000
VIENE DE FIGURA TT-5
Match to Figure TT-5
CONTINUA EN FIG TT-7
Match to Figure TT-7
0
500
1000 ms
ESCALA EN METROS
PLANTA
Plan
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
45.00
40.00
35.00
30.00
25.00
10+280
PUENTE
Bridge
CANAL REVESTIDO
Lined Channel Section
CANAL DE ADUCCION BRITO
BRITO ENTRANCE CHANNEL
PLANTA Y PERFIL
PLAN AND PROFILE
STA. 7+000 to STA. 14+000
7+000
8+000
9+000
10+000
11+000
12+000
13+000
14+000


PLANTA
Plan
0
500
1000 m
ESCALA EN METROS
14+000
15+000
16+000
17+000
18+000
VIENE DE LA FIGURA 77-6
CANAL DE ADUCCION QUITO
45.00
40.00
35.00
30.00
25.00
20.00
15.00
CANAL SIN REVESTIR
PLANTA Y PERFIL
PLAN AND PROFILE

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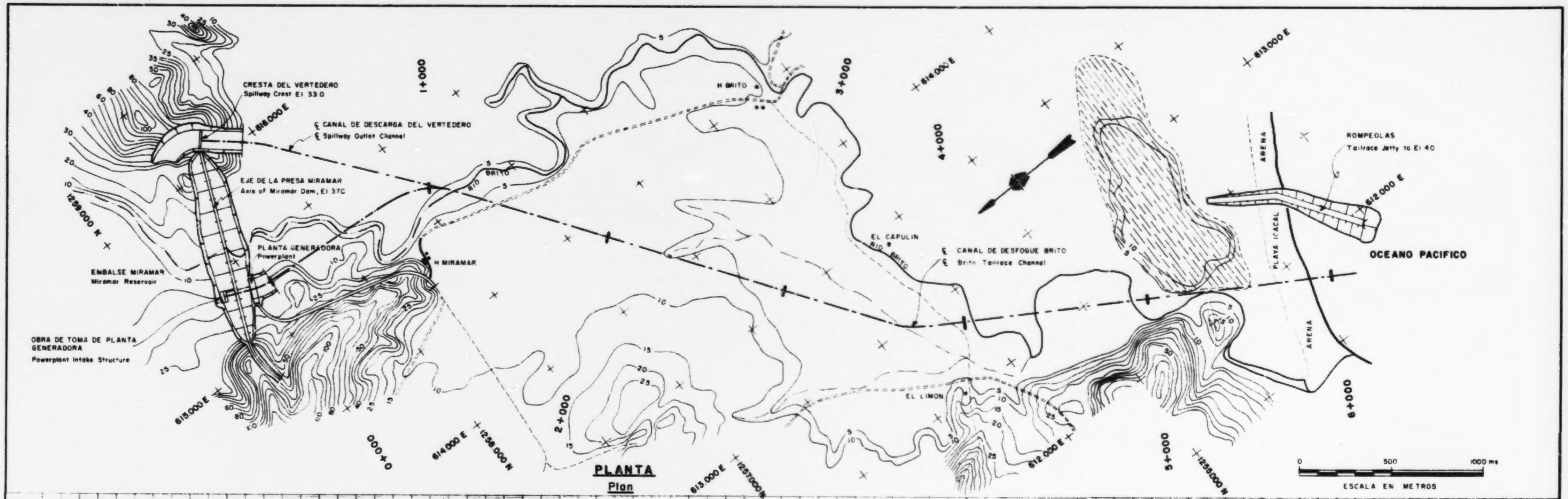
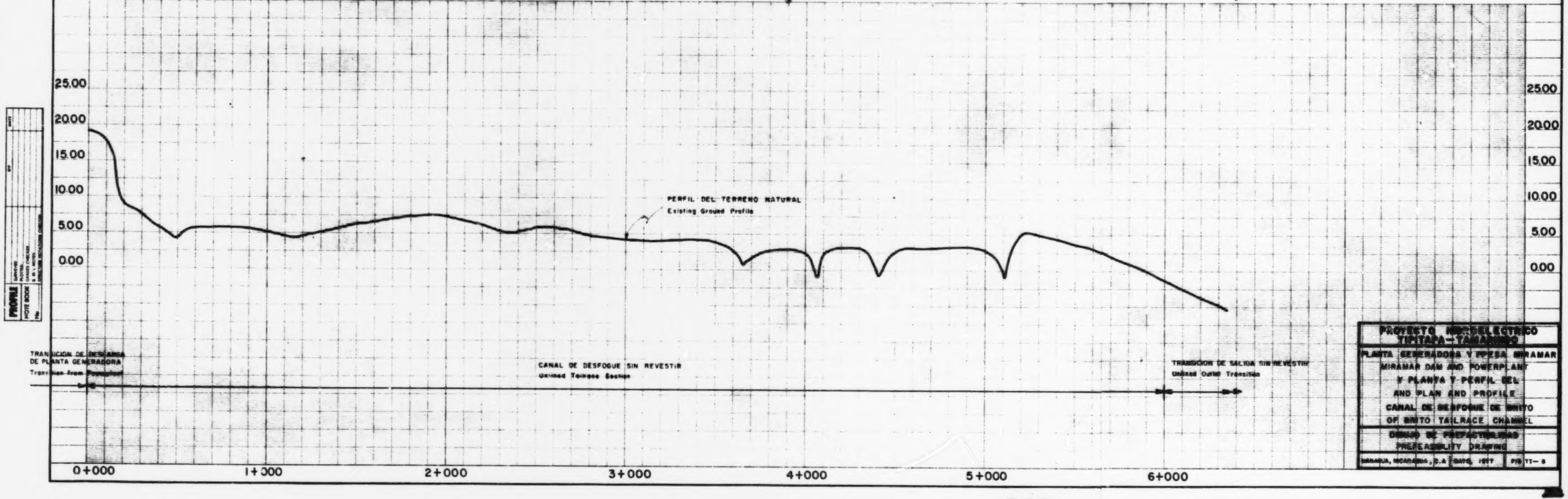

CRESTA DEL VERTEDERO
Spillway Crest El 33.0
616,000 E
℄ CANAL DE DESCARGA DEL VERTEDERO
℄ Spillway Outlet Channel
EJE DE LA PRESA MIRAMAR
Axis of Miramar Dam, El 37.0
PLANTA GENERADORA
Powerplant
EMBALSE MIRAMAR
Miramar Reservoir
OBRA DE TOMA DE PLANTA GENERADORA
Powerplant Intake Structure
1,259,000 N
615,000 E
0+000
614,000 E
1,258,000 N
1+000
2+000
3+000
4+000
5+000
6+000
H MIRAMAR
RIO BRITO
H BRITO
614,000 E
613,000 E
1,257,000 N
EL CAPULIN
℄ CANAL DE DESFOGUE BRITO
℄ Brito Tailrace Channel
EL LIMON
612,000 E
1,256,000 N
613,000 E
ROMPEOLAS
Tailrace Jetty to El 4.0
612,000 E
ARENA
PLAYA ICACAL
OCEANO PACIFICO
0
500
1000 ms
ESCALA EN METROS

PLANTA
Plan

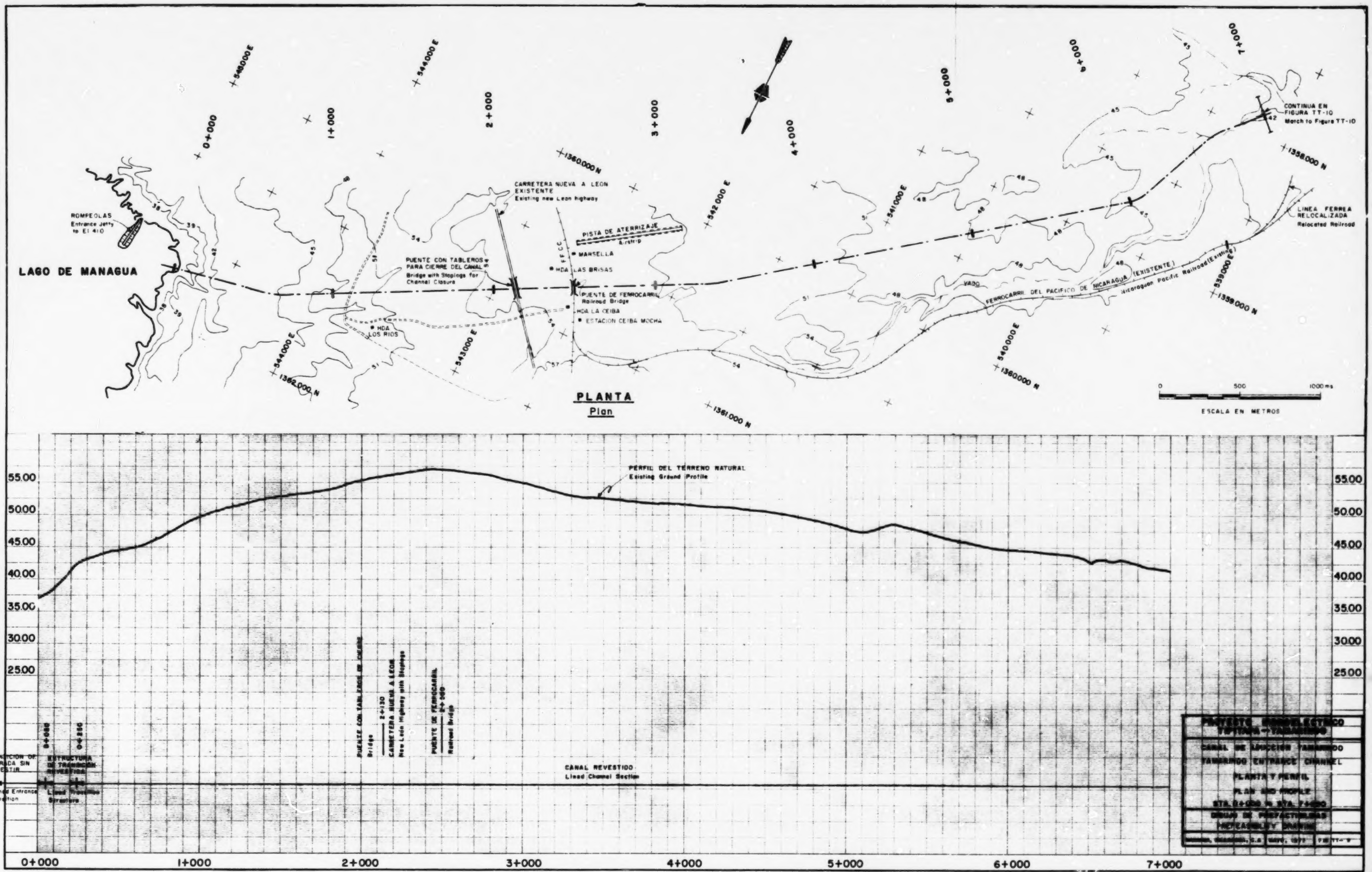


PROYECTO HIDROELECTRICO
TIPITAPA–TAMARINDO

PLANTA GENERADORA Y PRESA MIRAMAR
MIRAMAR DAM AND POWERPLANT
Y PLANTA Y PERFIL DEL
AND PLAN AND PROFILE
CANAL DE DESFOGUE DE BRITO
OF BRITO TAILRACE CHANNEL

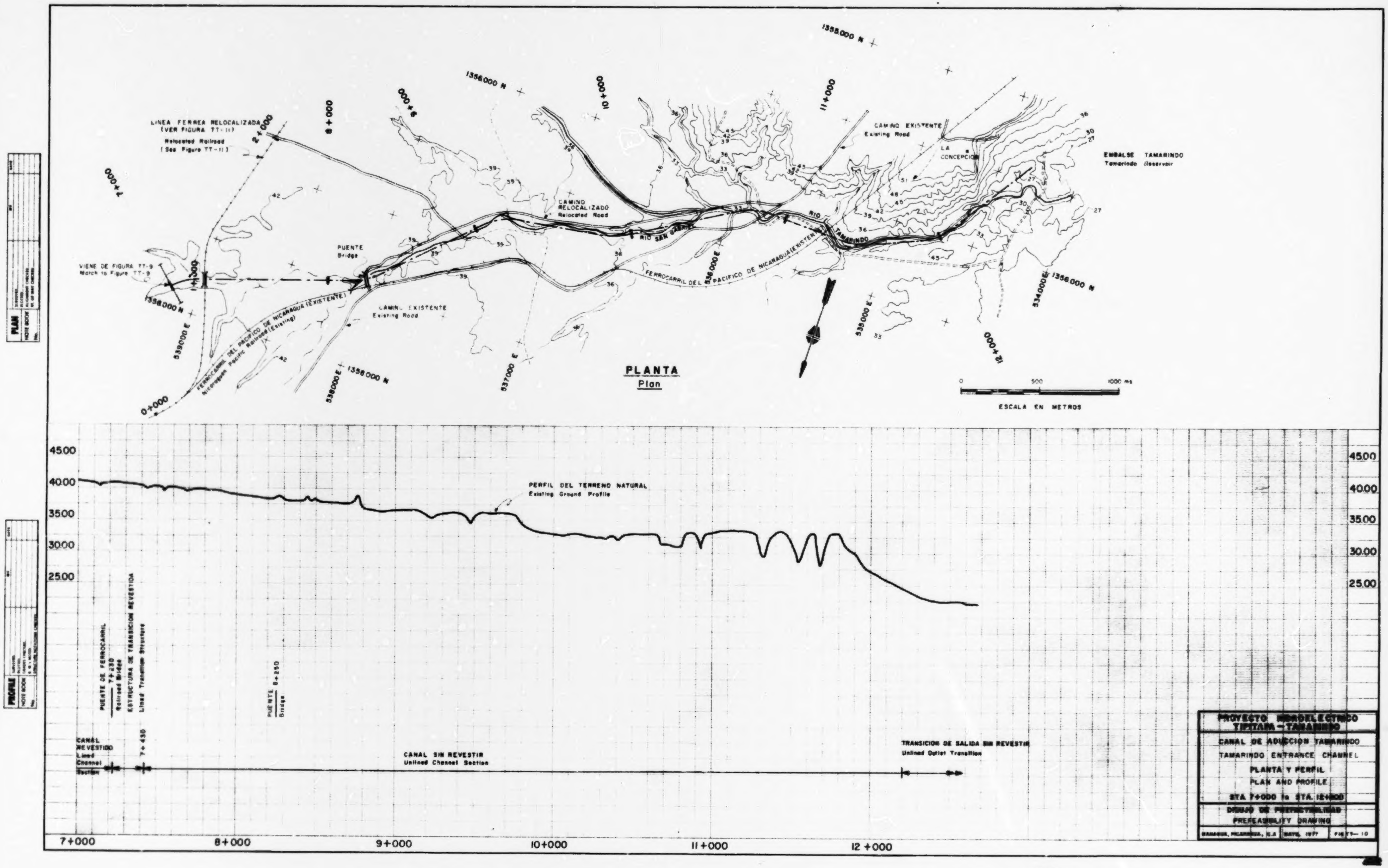
DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A | MAYO, 1977 | FIG. TT- 8


LAGO DE MANAGUA
ROMPEOLAS
Entrance Jetty to El 410
0+000
1+000
2+000
3+000
4+000
5+000
6+000
7+000
546000 E
544000 E
543000 E
542000 E
541000 E
540000 E
539000 E
1360000 N
1362000 N
1361000 N
1359000 N
1358000 N
CARRETERA NUEVA A LEON EXISTENTE
Existing new Leon highway
PUENTE CON TABLEROS PARA CIERRE DEL CANAL
Bridge with Stoplogs for Channel Closure
PISTA DE ATERRIZAJE
Airstrip
MARSELLA
HDA LAS BRISAS
PUENTE DE FERROCARRIL
Railroad Bridge
HDA LA CEIBA
ESTACION CEIBA MOCHA
HDA LOS RIOS
F.F.C.C.
VADO
FERROCARRIL DEL PACIFICO DE NICARAGUA (EXISTENTE)
Nicaraguan Pacific Railroad (Existing)
LINEA FERREA RELOCALIZADA
Relocated Railroad
CONTINUA EN FIGURA TT-10
Match to Figure TT-10
ESCALA EN METROS
0
500
1000 ms
PLANTA
Plan
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
55.00
50.00
45.00
40.00
35.00
30.00
25.00
TRANSICION DE ENTRADA SIN REVESTIR
Unlined Entrance Transition
0+080
0+250
ESTRUCTURA DE TRANSICION REVESTIDA
Lined Transition Structure
PUENTE CON TABLEROS DE CIERRE
Bridge
2+130
CARRETERA NUEVA A LEON
New Leon Highway with Stoplogs
PUENTE DE FERROCARRIL
2+260
Railroad Bridge
CANAL REVESTIDO
Lined Channel Section
0+000
1+000
2+000
3+000
4+000
5+000
6+000
7+000
PROYECTO HIDROELECTRICO TIPITAPA-TAMARINDO
CANAL DE ADUCCION TAMARINDO
TAMARINDO ENTRANCE CHANNEL
PLANTA Y PERFIL
PLAN AND PROFILE
STA. 0+000 to STA. 7+050
DIBUJO DE FACTIBILIDAD
FEASIBILITY DRAWING
MAYO, 1977
FIG. TT-9
PLAN
PROFILE
NOTE BOOK
No.

239

240


1358.000 N
1358.000 N
7+000
8+000
9+000
10+000
11+000
12+000
LINEA FERREA RELOCALIZADA
(VER FIGURA TT-11)
Relocated Railroad
(See Figure TT-11)
VIENE DE FIGURA TT-9
Match to Figure TT-9
1358.000 N
539000 E
538000 E
537000 E
536000 E
535000 E
534000 E
1356.000 N
PUENTE
Bridge
CAMINO RELOCALIZADO
Relocated Road
RIO SAN
RIO TAMARINDO
CAMINO EXISTENTE
Existing Road
LA CONCEPCION
EMBALSE TAMARINDO
Tamarindo Reservoir
FERROCARRIL DEL PACIFICO DE NICARAGUA (EXISTENTE)
Nicaraguan Pacific Railroad (Existing)
FERROCARRIL DEL PACIFICO DE NICARAGUA (EXISTENTE)
0+000
42
39
36
33
30
27
45
48
51
0
500
1000 ms
ESCALA EN METROS
PLANTA
Plan
45.00
40.00
35.00
30.00
25.00
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
PUENTE DE FERROCARRIL
7+230
Railroad Bridge
ESTRUCTURA DE TRANSICION REVESTIDA
Lined Transition Structure
PUENTE 8+250
Bridge
CANAL REVESTIDO
Lined Channel Section
7+430
CANAL SIN REVESTIR
Unlined Channel Section
TRANSICION DE SALIDA SIN REVESTIR
Unlined Outlet Transition
7+000
8+000
9+000
10+000
11+000
12+000
PLAN
PROFILE
NOTE BOOK

PROYECTO HIDROELECTRICO
TIPITAPA – TAMARINDO

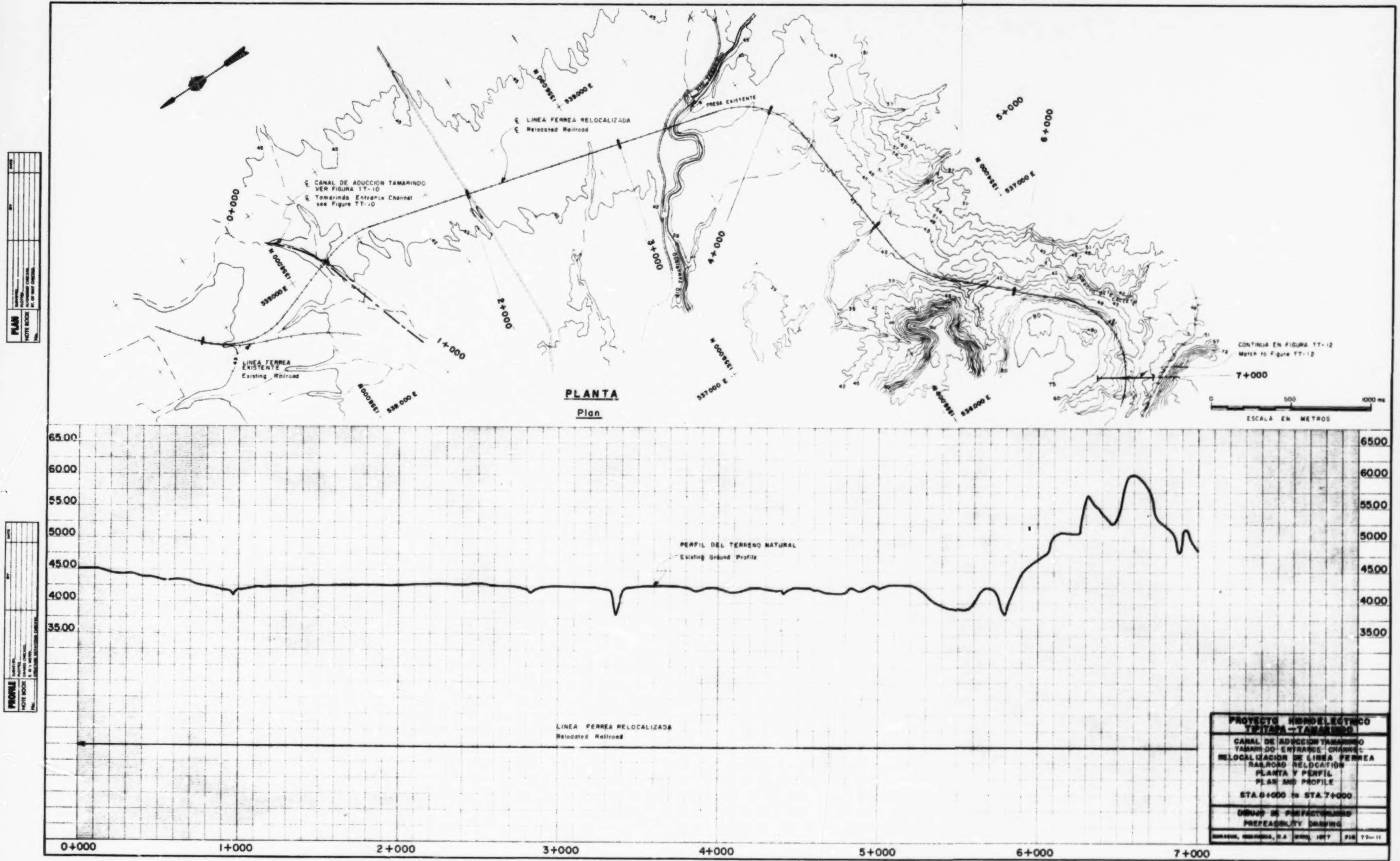
CANAL DE ADUCCION TAMARINDO
TAMARINDO ENTRANCE CHANNEL

PLANTA Y PERFIL
PLAN AND PROFILE

STA 7+000 to STA. 12+600

DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A | MAYO, 1977 | FIG TT-10


PLANTA
Plan
℄ LINEA FERREA RELOCALIZADA
℄ Relocated Railroad
℄ CANAL DE ADUCCION TAMARINDO VER FIGURA TT-10
℄ Tamarindo Entrance Channel see Figure TT-10
LINEA FERREA EXISTENTE
Existing Railroad
PRESA EXISTENTE
CONTINUA EN FIGURA TT-12
Match to Figure TT-12
ESCALA EN METROS
0
500
1000 ms
0+000
1+000
2+000
3+000
4+000
5+000
6+000
7+000
1360000 N
1361000 N
1362000 N
1363000 N
536000 E
537000 E
538000 E
539000 E
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
LINEA FERREA RELOCALIZADA
Relocated Railroad
65.00
60.00
55.00
50.00
45.00
40.00
35.00
PLAN
NOTE BOOK
PROFILE
NOTE BOOK

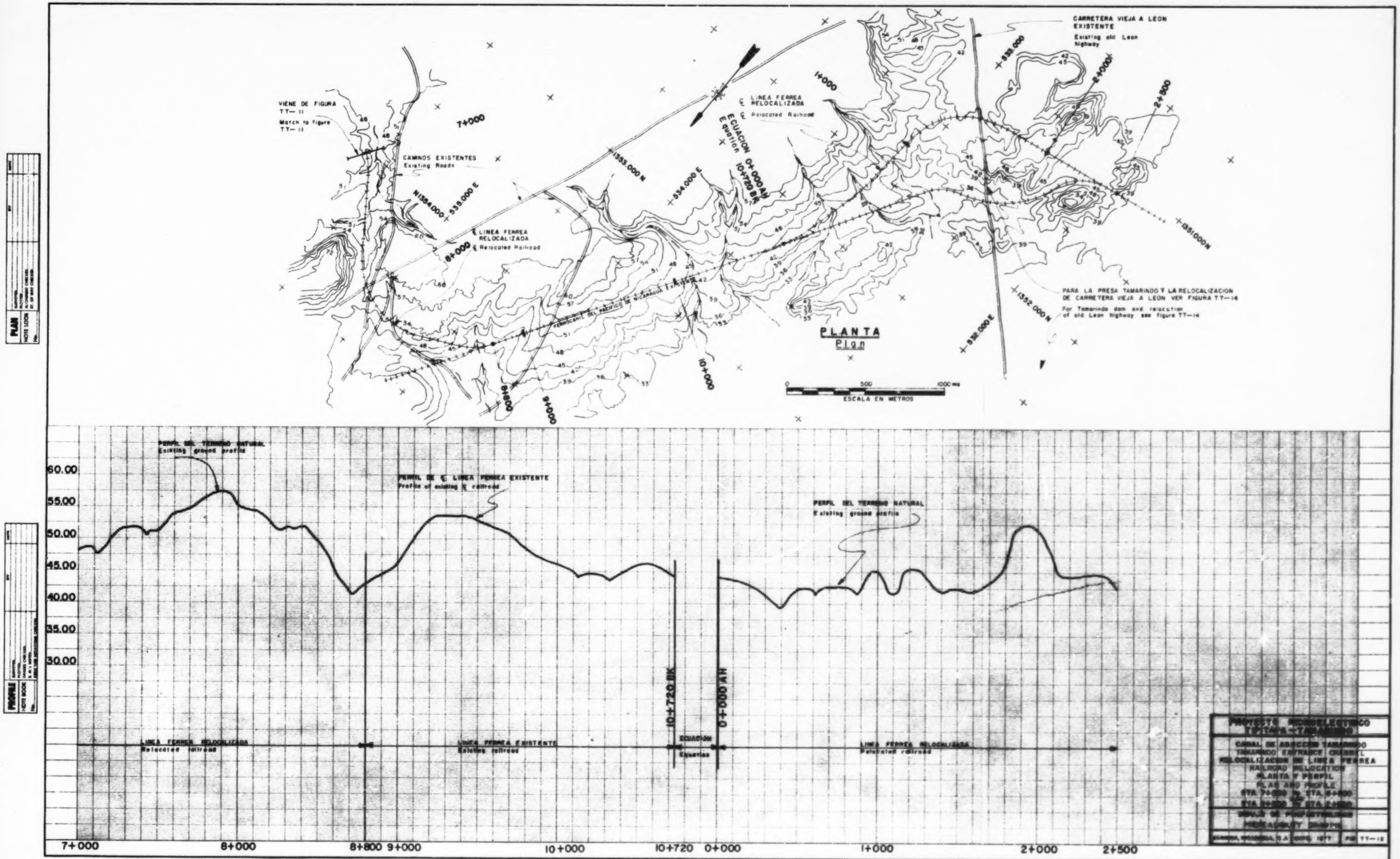
PROYECTO HIDROELECTRICO
TIPITAPA–TAMARINDO

CANAL DE ADUCCION TAMARINDO
TAMARINDO ENTRANCE CHANNEL
RELOCALIZACION DE LINEA FERREA
RAILROAD RELOCATION
PLANTA Y PERFIL
PLAN AND PROFILE

STA 0+000 to STA 7+000

DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A [illegible] 1977 FIG TT-11


VIENE DE FIGURA TT-11
Match to figure TT-11
CAMINOS EXISTENTES
Existing Roads
7+000
8+000
N1354.000 - 535.000 E
1355.000 N
534.000 E
Ⓒ LINEA FERREA RELOCALIZADA
Ⓒ Relocated Railroad
ECUACION 0+000 AH
Equation 10+720 BK
1+000
2+000
2+500
10+000
8+800
9+000
CARRETERA VIEJA A LEON EXISTENTE
Existing old Leon highway
533.000
1351.000 N
1352.000 N
532.000 E
PARA LA PRESA TAMARINDO Y LA RELOCALIZACION DE CARRETERA VIEJA A LEON VER FIGURA TT-14
For Tamarindo dam and relocation of old Leon highway see figure TT-14
PLANTA
Plan
0
500
1000 ms
ESCALA EN METROS
PLAN
NOTE BOOK
No.
PROFILE
NOTE BOOK
No.
PERFIL DEL TERRENO NATURAL
Existing ground profile
PERFIL DE Ⓒ LINEA FERREA EXISTENTE
Profile of existing Ⓒ railroad
PERFIL DEL TERRENO NATURAL
Existing ground profile
60.00
55.00
50.00
45.00
40.00
35.00
30.00
10+720 BK
0+000 AH
LINEA FERREA RELOCALIZADA
Relocated railroad
LINEA FERREA EXISTENTE
Existing railroad
ECUACION
Equation
LINEA FERREA RELOCALIZADA
Relocated railroad
7+000
8+000
8+800
9+000
10+000
10+720
0+000
1+000
2+000
2+500

PROYECTO HIDROELECTRICO
TIPITAPA-TAMARINDO

CANAL DE ADUCCION TAMARINDO
TAMARINDO ENTRANCE CHANNEL
RELOCALIZACION DE LINEA FERREA
RAILROAD RELOCATION
PLANTA Y PERFIL
PLAN AND PROFILE
STA 7+000 TO STA 8+800
STA 0+000 TO STA 2+500

[illegible]
[illegible]

MANAGUA, NICARAGUA, C.A. [illegible] 1977 FIG TT-12

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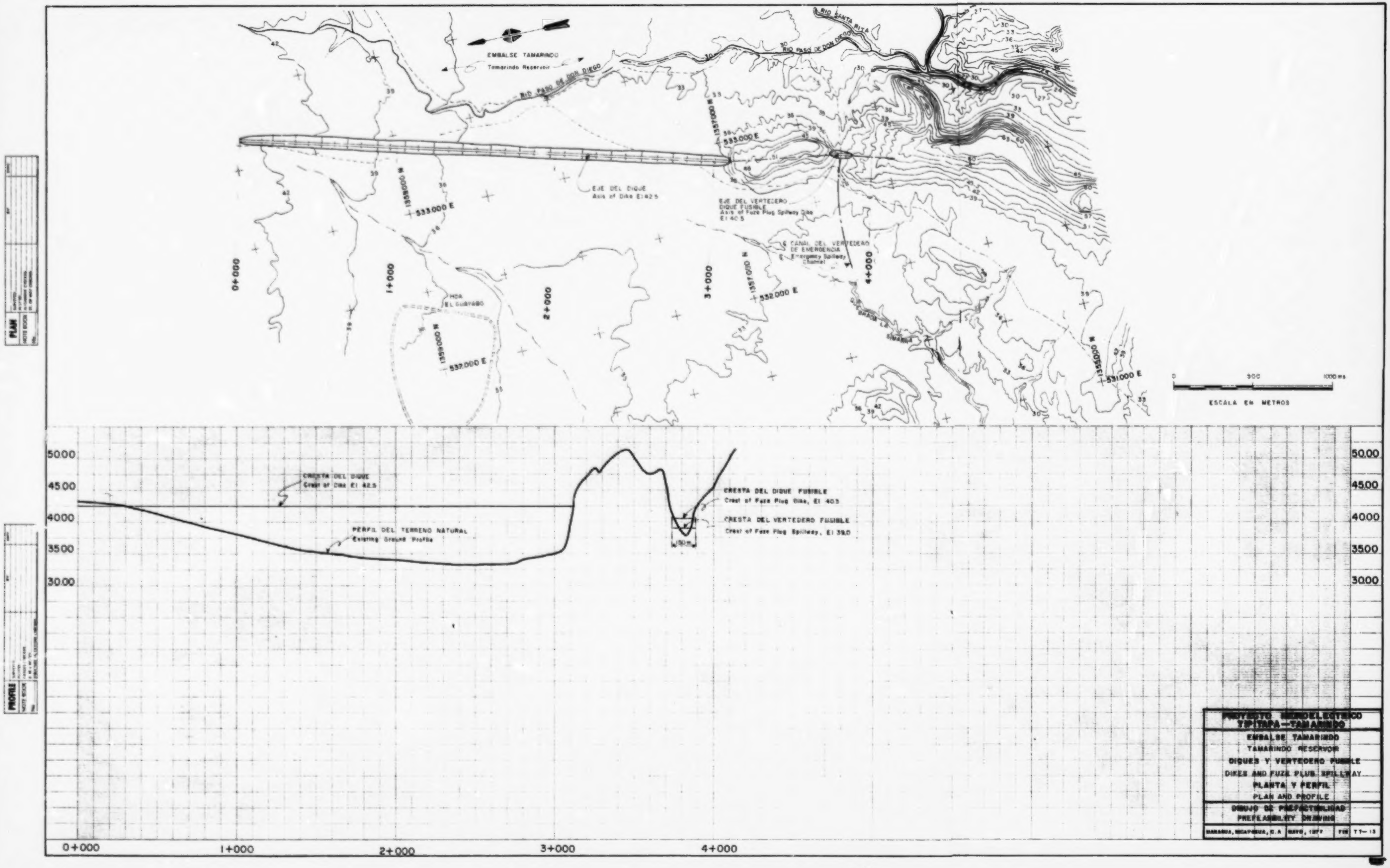
Blank Page


EMBALSE TAMARINDO
Tamarindo Reservoir
RIO SANTA RITA
RIO PASO DE DON DIEGO
EJE DEL DIQUE
Axis of Dike El 42.5
EJE DEL VERTEDERO
DIQUE FUSIBLE
Axis of Fuze Plug Spillway Dike
El 40.5
℄ CANAL DEL VERTEDERO
DE EMERGENCIA
Emergency Spillway
Channel
HDA
EL GUAYABO
QDA. BRAOS LA SHAMBA
1358000 N
533000 E
1357000 N
532000 E
1359000 N
1356000 N
531000 E
0+000
1+000
2+000
3+000
4+000
0
500
1000 m
ESCALA EN METROS
CRESTA DEL DIQUE
Crest of Dike El 42.5
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
CRESTA DEL DIQUE FUSIBLE
Crest of Fuze Plug Dike, El 40.5
CRESTA DEL VERTEDERO FUSIBLE
Crest of Fuze Plug Spillway, El 39.0
150 m
50.00
45.00
40.00
35.00
30.00
PLAN
PROFILE

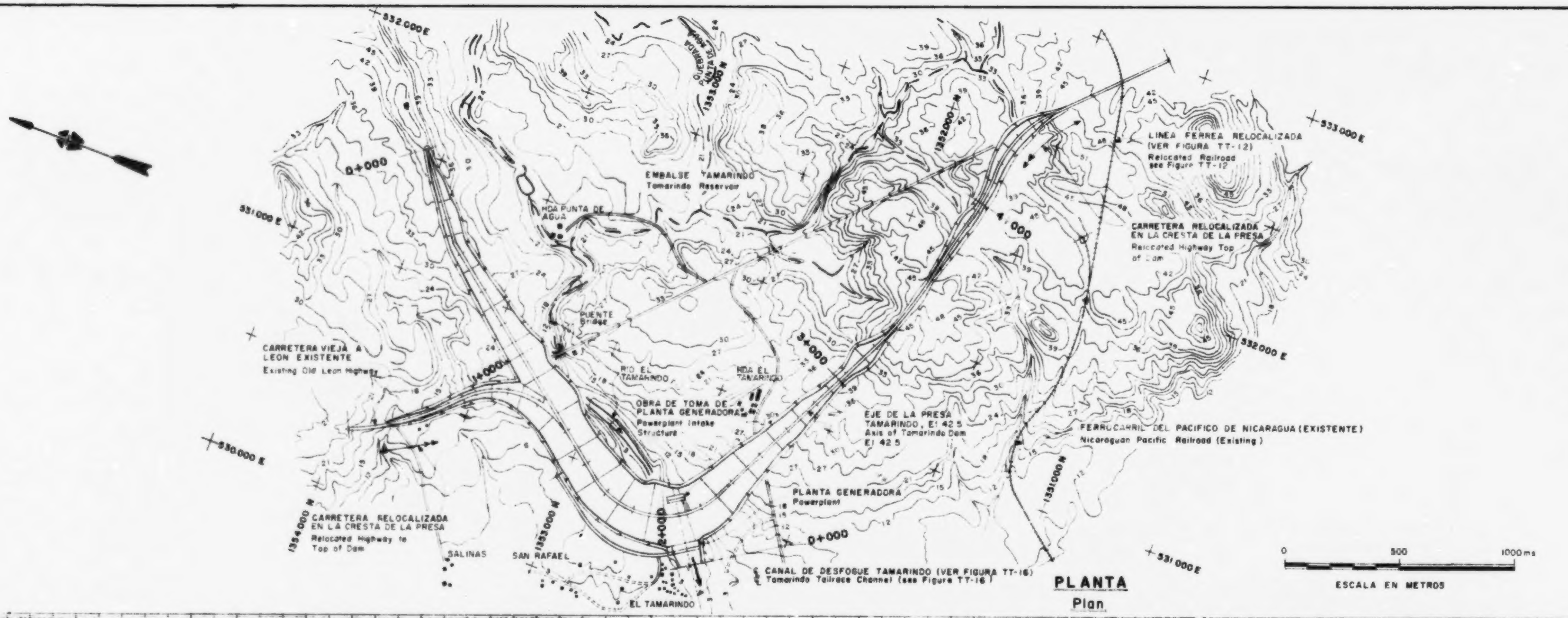
PROYECTO HIDROELECTRICO
TIPITAPA—TAMARINDO

EMBALSE TAMARINDO
TAMARINDO RESERVOIR
DIQUES Y VERTEDERO FUSIBLE
DIKES AND FUZE PLUG SPILLWAY
PLANTA Y PERFIL
PLAN AND PROFILE

DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A.	MAYO, 1977	FIG	TT-13

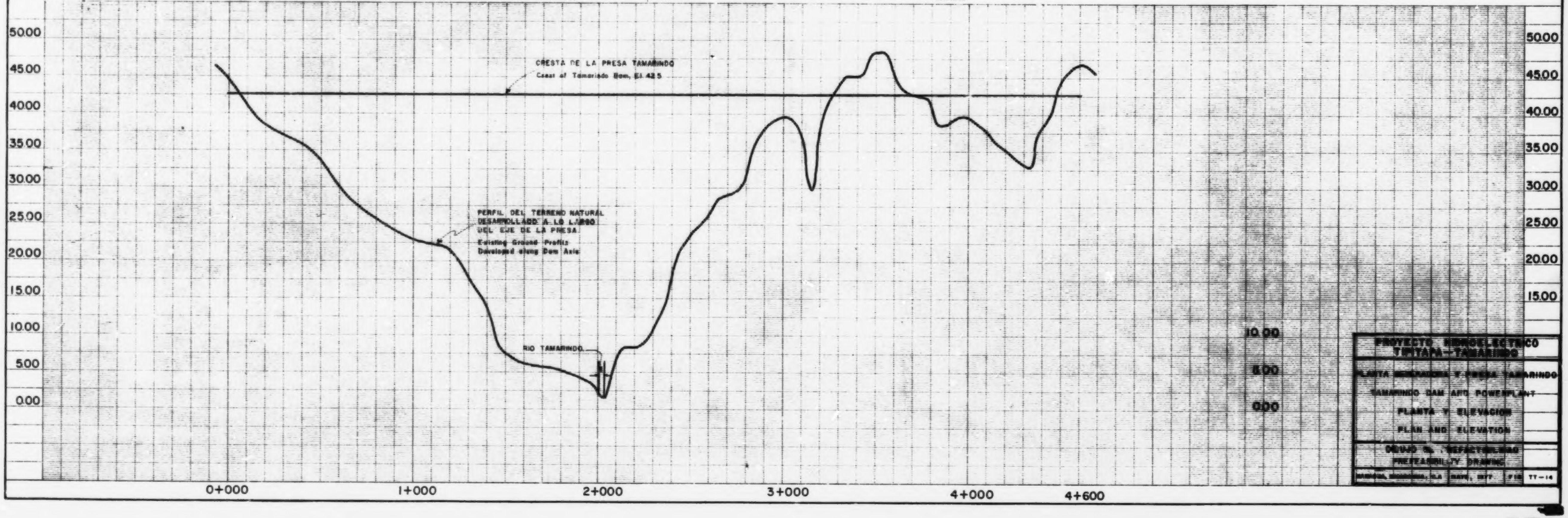
PLAN
NOTE BOOK
No.


532.000 E
QUEBRADA PUNTA DE AGUA
1353000 N
0+000
EMBALSE TAMARINDO
Tamarindo Reservoir
531.000 E
HDA PUNTA DE AGUA
PUENTE
Bridge
1352000 N
LINEA FERREA RELOCALIZADA (VER FIGURA TT-12)
Relocated Railroad see Figure TT-12
533.000 E
4+000
CARRETERA RELOCALIZADA EN LA CRESTA DE LA PRESA
Relocated Highway Top of Dam
CARRETERA VIEJA A LEON EXISTENTE
Existing Old Leon Highway
1+000
RIO EL TAMARINDO
HDA EL TAMARINDO
3+000
532.000 E
OBRA DE TOMA DE PLANTA GENERADORA
Powerplant Intake Structure
EJE DE LA PRESA TAMARINDO, El 42.5
Axis of Tamarindo Dam El 42.5
FERROCARRIL DEL PACIFICO DE NICARAGUA (EXISTENTE)
Nicaraguan Pacific Railroad (Existing)
530.000 E
PLANTA GENERADORA
Powerplant
1351000 N
CARRETERA RELOCALIZADA EN LA CRESTA DE LA PRESA
Relocated Highway to Top of Dam
1354000 N
1353000 N
2+000
0+000
531.000 E
0
500
1000 ms
ESCALA EN METROS
SALINAS
SAN RAFAEL
CANAL DE DESFOGUE TAMARINDO (VER FIGURA TT-16)
Tamarindo Tailrace Channel (see Figure TT-16)
EL TAMARINDO

PLANTA

Plan

PROFILE
NOTE BOOK
No.



PROYECTO HIDROELECTRICO
TIPITAPA—TAMARINDO

PLANTA GENERADORA Y PRESA TAMARINDO

TAMARINDO DAM AND POWERPLANT

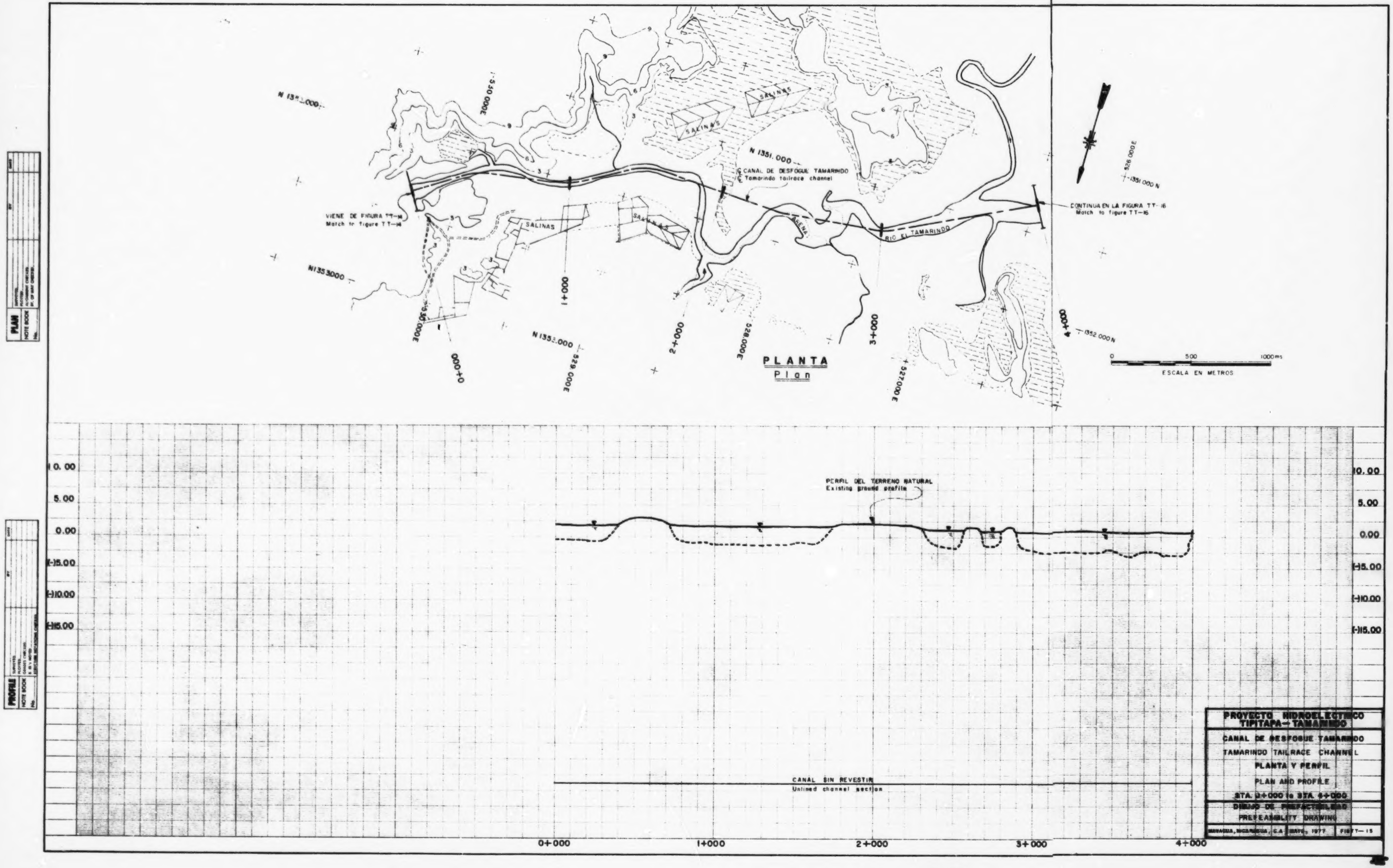
PLANTA Y ELEVACION

PLAN AND ELEVATION

DIBUJO DE PREFACTIBILIDAD

PREFEASIBILITY DRAWING

[illegible] MAYO, 1977 FIG TT-14


N 1352.000
3000 055
VIENE DE FIGURA TT-14
Match to figure TT-14
SALINAS
SALINAS
SALINAS
SALINAS
N1353000
N 1351.000
℄ CANAL DE DESFOGUE TAMARINDO
℄ Tamarindo tailrace channel
RIO EL TAMARINDO
CONTINUA EN LA FIGURA TT-16
Match to figure TT-16
526 000 E
1351.000 N
1352.000 N
N 1353.000
529 000 E
528 000 E
527000 E
0+000
1+000
2+000
3+000
4+000
PLANTA
Plan
0
500
1000ms
ESCALA EN METROS
PLAN
NOTE BOOK
No.
PROFILE
NOTE BOOK
No.
10.00
5.00
0.00
(-)5.00
(-)10.00
(-)15.00
PERFIL DEL TERRENO NATURAL
Existing ground profile
CANAL SIN REVESTIR
Unlined channel section
0+000
1+000
2+000
3+000
4+000

PROYECTO HIDROELECTRICO
TIPITAPA — TAMARINDO

CANAL DE DESFOGUE TAMARINDO

TAMARINDO TAILRACE CHANNEL

PLANTA Y PERFIL

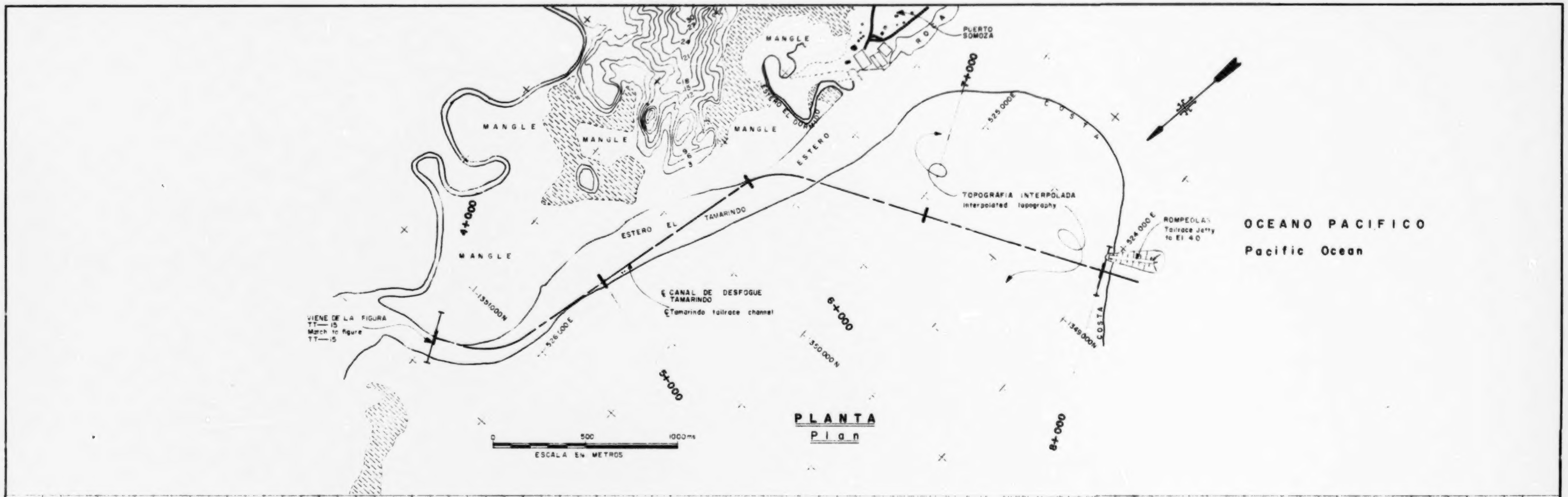
PLAN AND PROFILE

STA. 0+000 to STA. 4+000

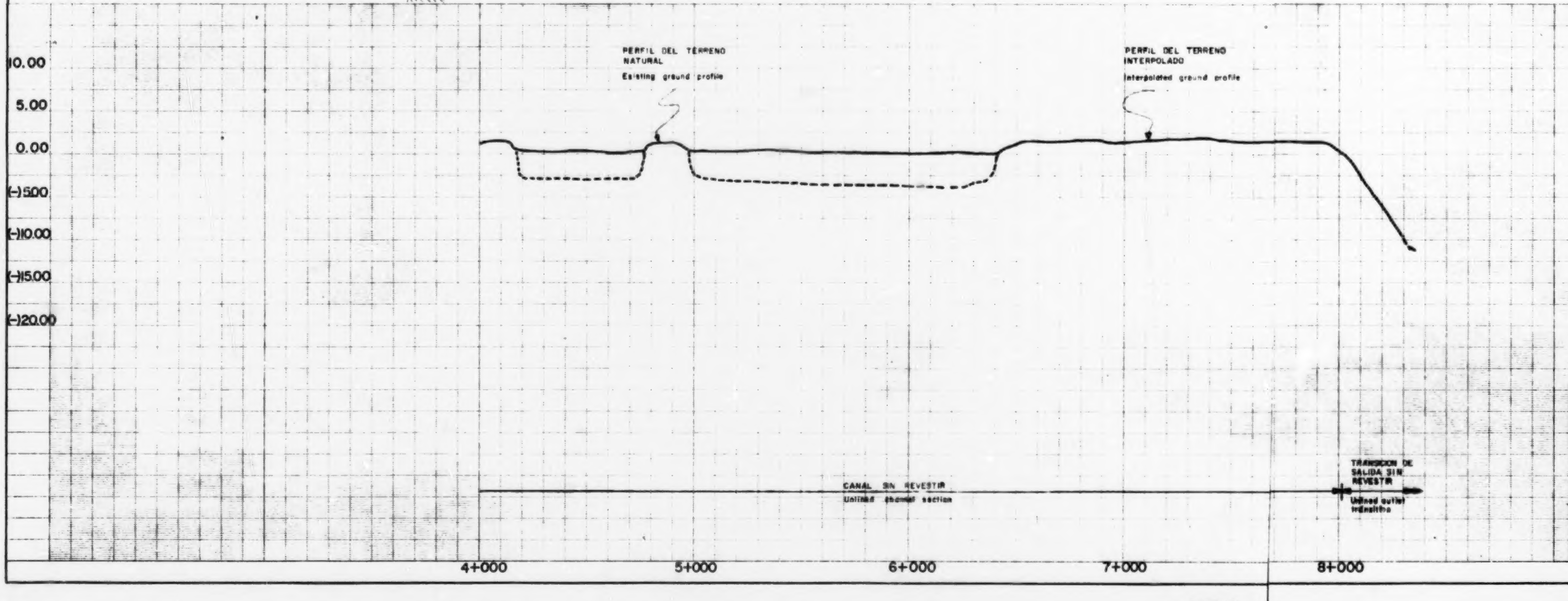
DIBUJO DE PREFACTIBILIDAD

PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A.	MAYO, 1977	FIG TT-15


MANGLE
MANGLE
MANGLE
MANGLE
MANGLE
ESTERO EL DURANGO
ESTERO
ESTERO EL TAMARINDO
ROTA
PUERTO SOMOZA
COSTA
COSTA
OCEANO PACIFICO
Pacific Ocean
TOPOGRAFIA INTERPOLADA
Interpolated topography
ROMPEOLAS
Tailrace Jetty to El 4.0
℄ CANAL DE DESFOGUE TAMARINDO
℄ Tamarindo tailrace channel
VIENE DE LA FIGURA TT—15
Match to figure TT—15
4+000
5+000
6+000
7+000
8+000
1351000 N
1350000 N
1349000 N
526000 E
525000 E
524000 E
0
500
1000 ms
ESCALA EN METROS

PLANTA
Plan



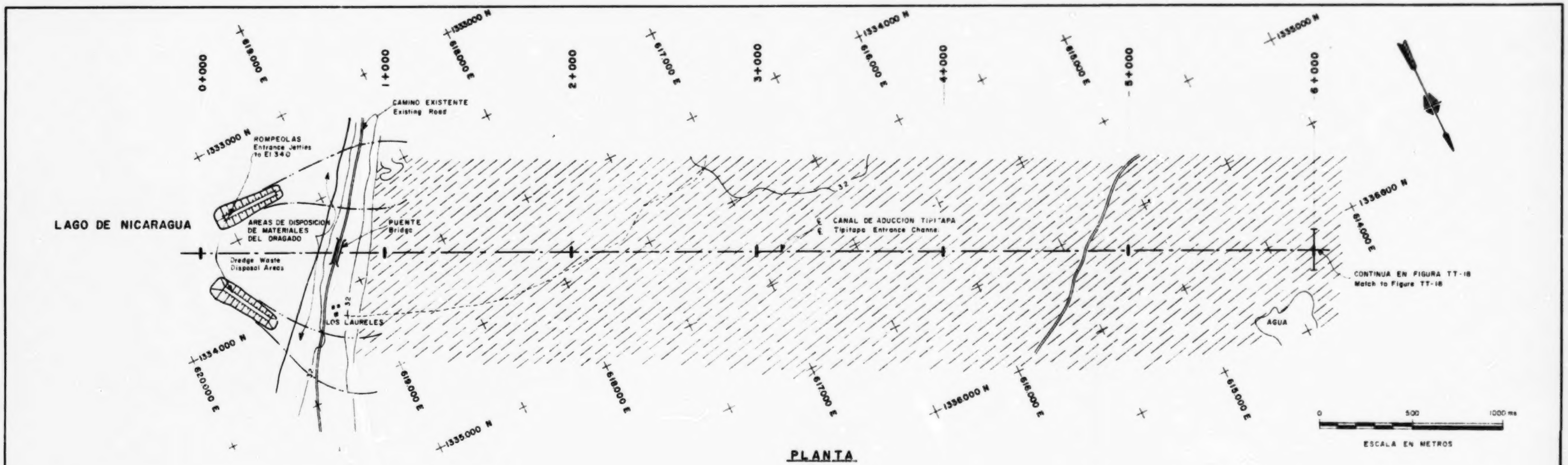
PROYECTO HIDROELECTRICO
TIPITAPA—TAMARINDO

CANAL DE DESFOGUE TAMARINDO
TAMARINDO TAILRACE CHANNEL
PLANTA Y PERFIL
PLAN AND PROFILE
STA. 4+000 to STA. 8+300

DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

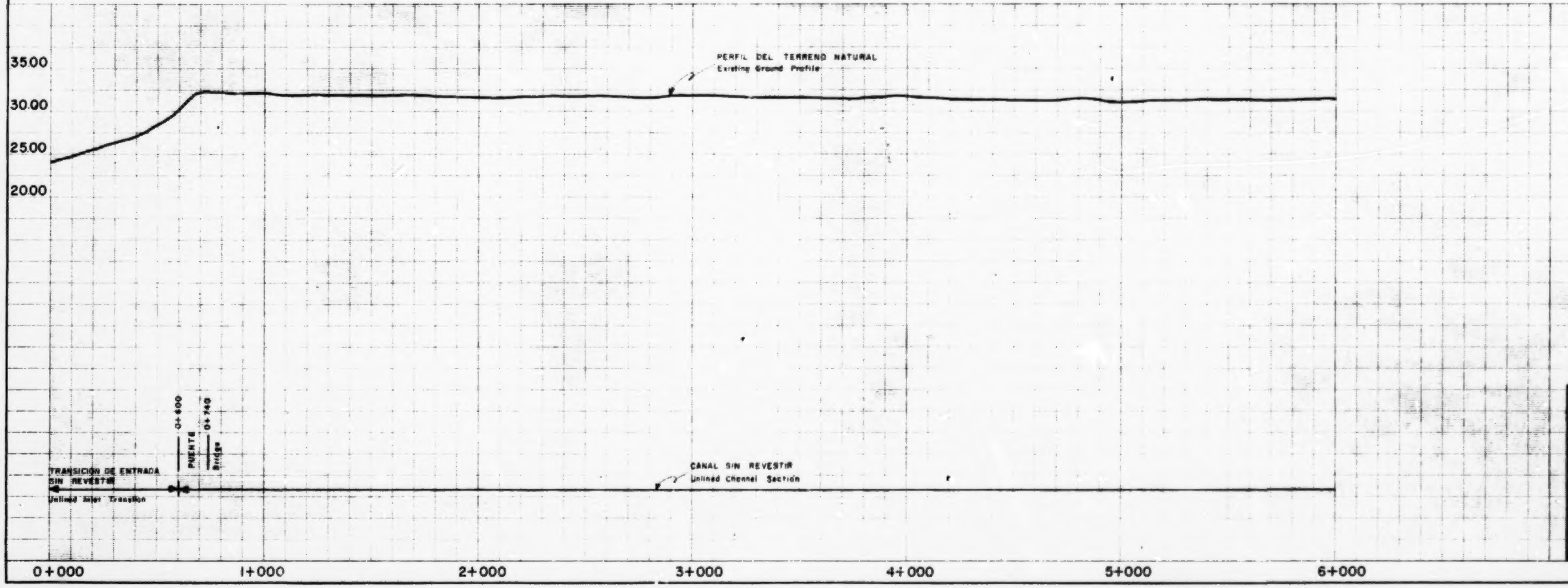
MANAGUA, NICARAGUA, C.A. | MAYO, 1977 | FIG. TT—16

PLAN
NOTE BOOK
No.


LAGO DE NICARAGUA
ROMPEOLAS
Entrance Jetties
to El 34.0
AREAS DE DISPOSICION
DE MATERIALES
DEL DRAGADO
Dredge Waste
Disposal Areas
CAMINO EXISTENTE
Existing Road
PUENTE
Bridge
LOS LAURELES
CANAL DE ADUCCION TIPITAPA
Tipitapa Entrance Channel
AGUA
CONTINUA EN FIGURA TT-18
Match to Figure TT-18
0+000
1+000
2+000
3+000
4+000
5+000
6+000
1333000 N
1334000 N
1335000 N
1336000 N
620000 E
619000 E
618000 E
617000 E
616000 E
615000 E
614000 E
32
0
500
1000 ms
ESCALA EN METROS

PLANTA
Plan

PROFILE
NOTE BOOK
No.

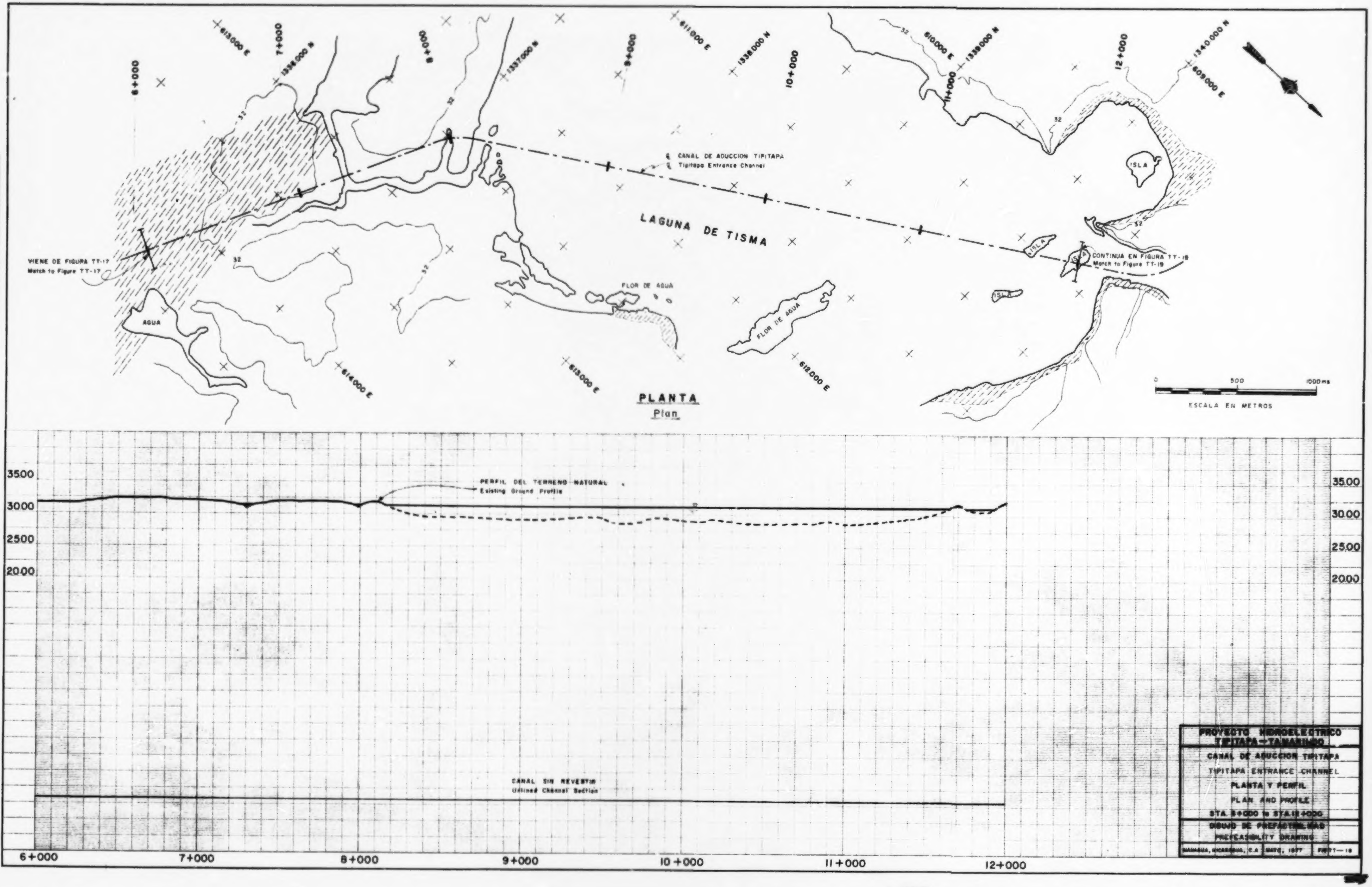


PROYECTO HIDROELECTRICO
TIPITAPA—TAMARINDO

CANAL DE ADUCCION TIPITAPA
TIPITAPA ENTRANCE CHANNEL
PLANTA Y PERFIL
PLAN AND PROFILE
STA. 0+000 to STA. 6+000

DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A	MAYO, 1977	FIG	TT-17

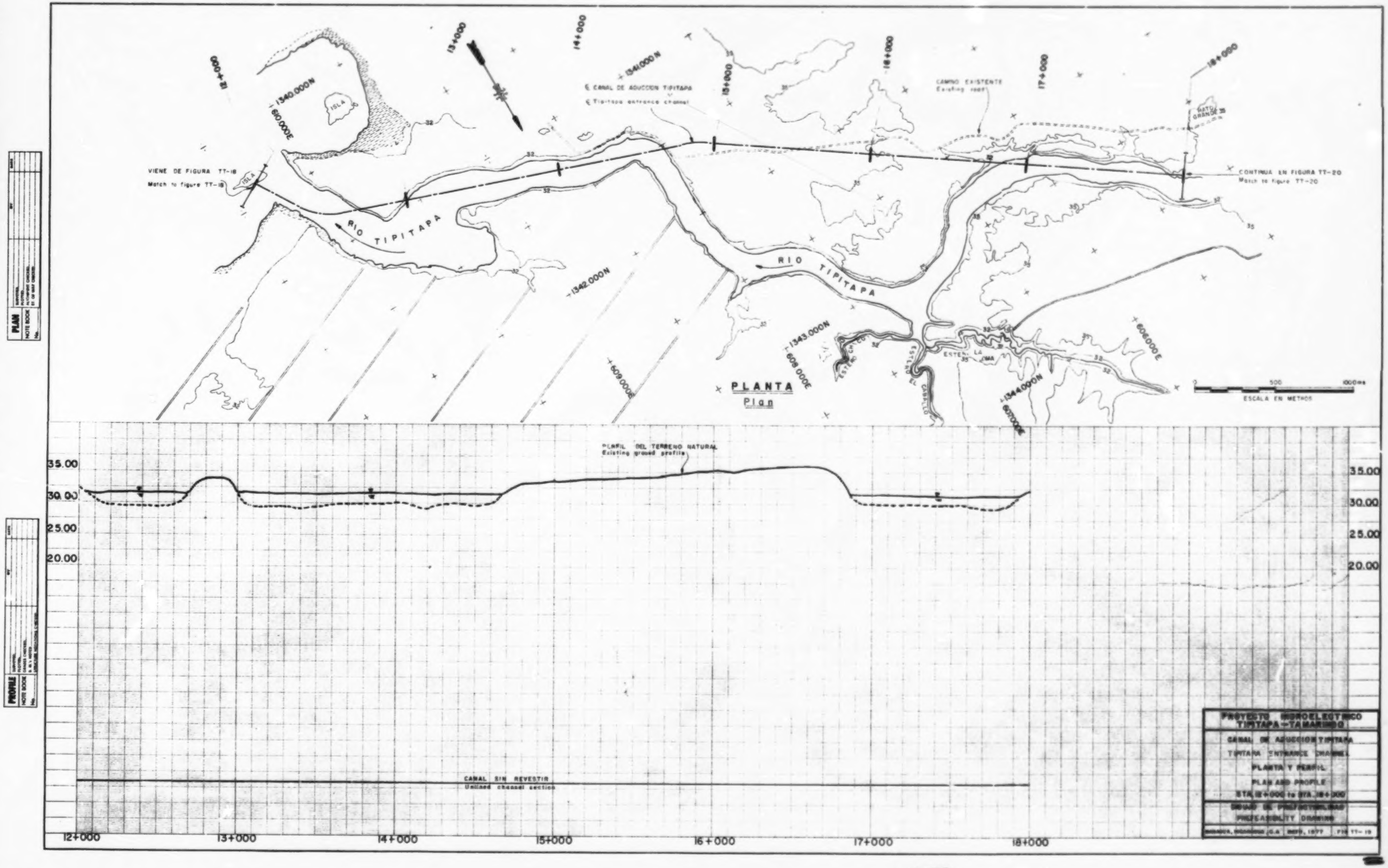

6+000
7+000
8+000
9+000
10+000
11+000
12+000
613000 E
1336000 N
1337000 N
611000 E
1338000 N
610000 E
1339000 N
1340000 N
609000 E
614000 E
613000 E
612000 E
32
℄ CANAL DE ADUCCION TIPITAPA
℄ Tipitapa Entrance Channel
LAGUNA DE TISMA
VIENE DE FIGURA TT-17
Match to Figure TT-17
CONTINUA EN FIGURA TT-19
Match to Figure TT-19
AGUA
FLOR DE AGUA
FLOR DE AGUA
ISLA
ISLA
ISLA
ISLA
0
500
1000 ms
ESCALA EN METROS
PLANTA
Plan
35.00
30.00
25.00
20.00
PERFIL DEL TERRENO NATURAL
Existing Ground Profile
CANAL SIN REVESTIR
Unlined Channel Section
6+000
7+000
8+000
9+000
10+000
11+000
12+000
PLAN
NOTE BOOK
No.
PROFILE
NOTE BOOK
No.

PROYECTO HIDROELECTRICO
TIPITAPA—TAMARINDO

CANAL DE ADUCCION TIPITAPA
TIPITAPA ENTRANCE CHANNEL
PLANTA Y PERFIL
PLAN AND PROFILE
STA. 6+000 to STA.12+000

DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A. | MAYO, 1977 | FIG. TT—18


VIENE DE FIGURA TT-18
Match to figure TT-18
CONTINUA EN FIGURA TT-20
Match to figure TT-20
℄ CANAL DE ADUCCION TIPITAPA
℄ Tipitapa entrance channel
CAMINO EXISTENTE
Existing road
RIO TIPITAPA
RIO TIPITAPA
ISLA
ISLA
12+000
13+000
14+000
15+000
16+000
17+000
18+000
1340,000N
1341,000N
1342,000N
1343,000N
1344,000N
606,000E
608,000E
609,000E
ESTERO EL CABALLO
ESTERO LA PALMA
32
35
0
500
1000ms
ESCALA EN METROS
PLANTA
Plan
PERFIL DEL TERRENO NATURAL
Existing ground profile
35.00
30.00
25.00
20.00
CANAL SIN REVESTIR
Unlined channel section
12+000
13+000
14+000
15+000
16+000
17+000
18+000
PLAN
NOTE BOOK
No.
PROFILE
NOTE BOOK
No.

PROYECTO HIDROELECTRICO
TIPITAPA-TAMARINDO

CANAL DE ADUCCION TIPITAPA

TIPITAPA ENTRANCE CHANNEL

PLANTA Y PERFIL

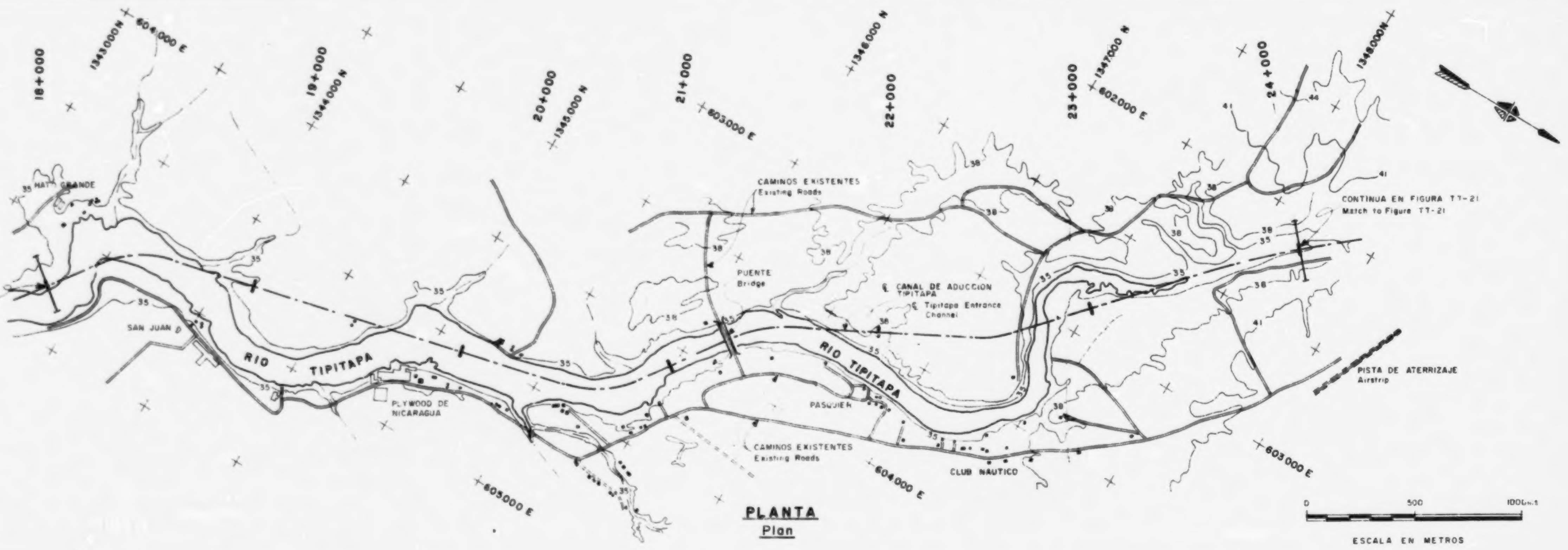
PLAN AND PROFILE

STA. 12+000 to STA. 18+000

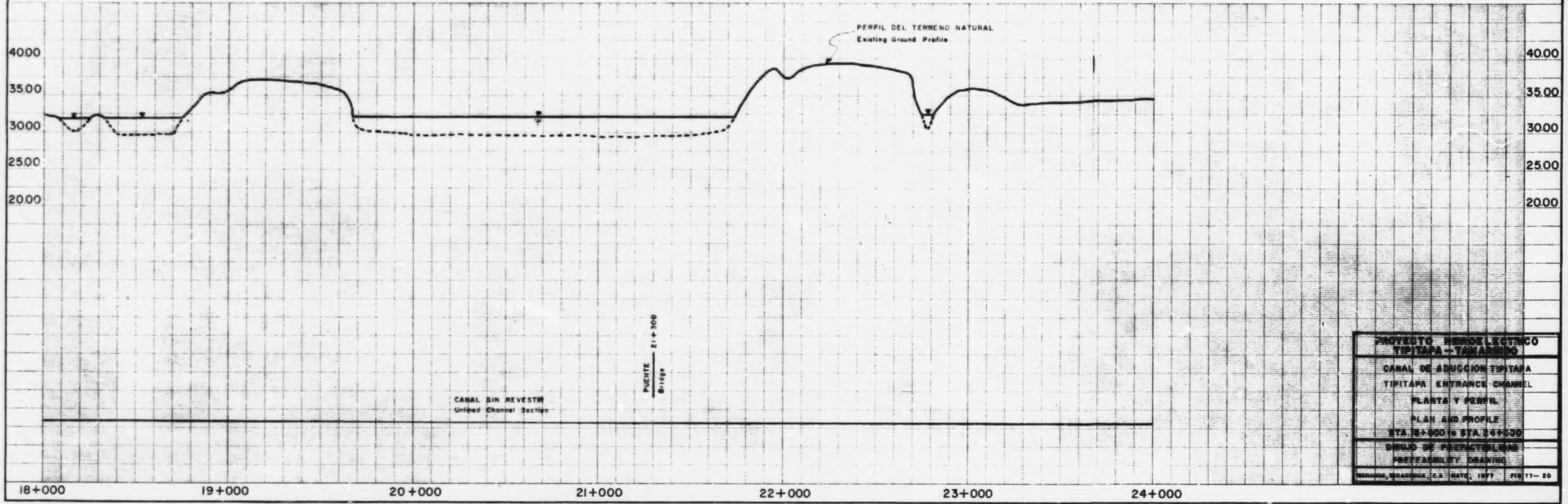
DIBUJO DE PREFACTIBILIDAD

PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A.	SEPT., 1977	FIG TT-19


18+000
19+000
20+000
21+000
22+000
23+000
24+000
1343000 N
604000 E
1344000 N
1345000 N
603000 E
1346000 N
1347000 N
602000 E
1348000 N
605000 E
604000 E
603000 E
35
38
41
44
NATI GRANDE
VIENE DE FIGURA TT-19
Match to Figure TT-19
SAN JUAN
RIO TIPITAPA
PLYWOOD DE NICARAGUA
CAMINOS EXISTENTES
Existing Roads
PUENTE
Bridge
℄ CANAL DE ADUCCION TIPITAPA
℄ Tipitapa Entrance Channel
PASQUIER
CLUB NAUTICO
CONTINUA EN FIGURA TT-21
Match to Figure TT-21
PISTA DE ATERRIZAJE
Airstrip
0
500
1000
ESCALA EN METROS

PLANTA
Plan



PLAN
NOTE BOOK
No.

PROFILE
NOTE BOOK
No.

PROYECTO HIDROELECTRICO
TIPITAPA—TAMARINDO

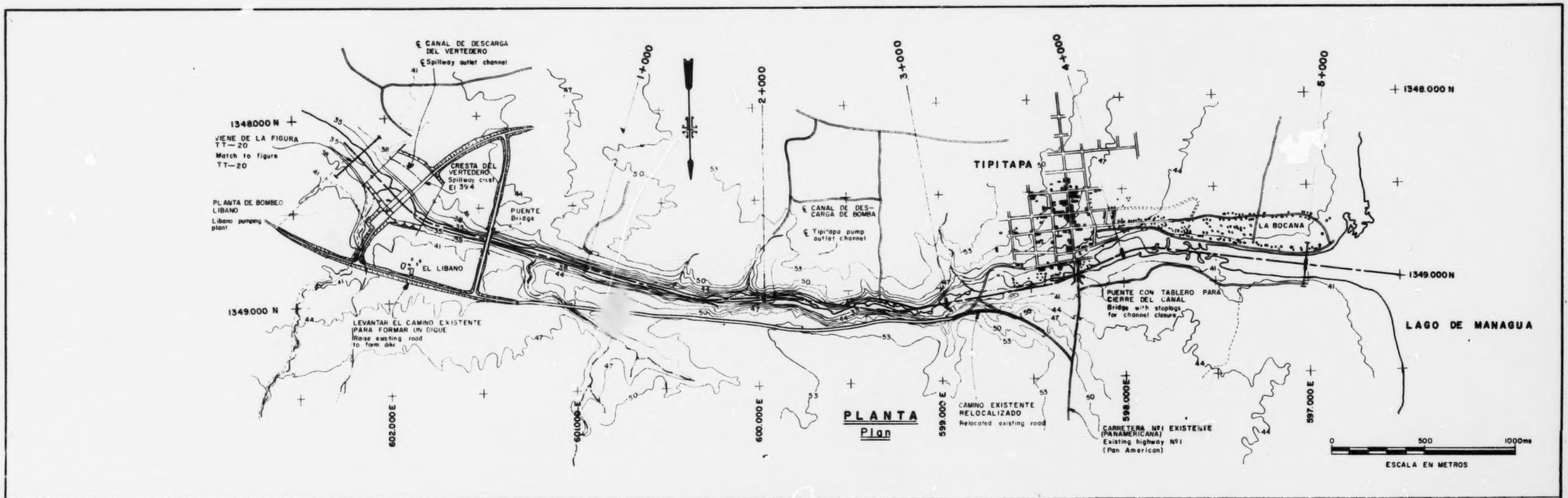
CANAL DE ADUCCION TIPITAPA
TIPITAPA ENTRANCE CHANNEL
PLANTA Y PERFIL
PLAN AND PROFILE
STA.18+000 to STA.24+000

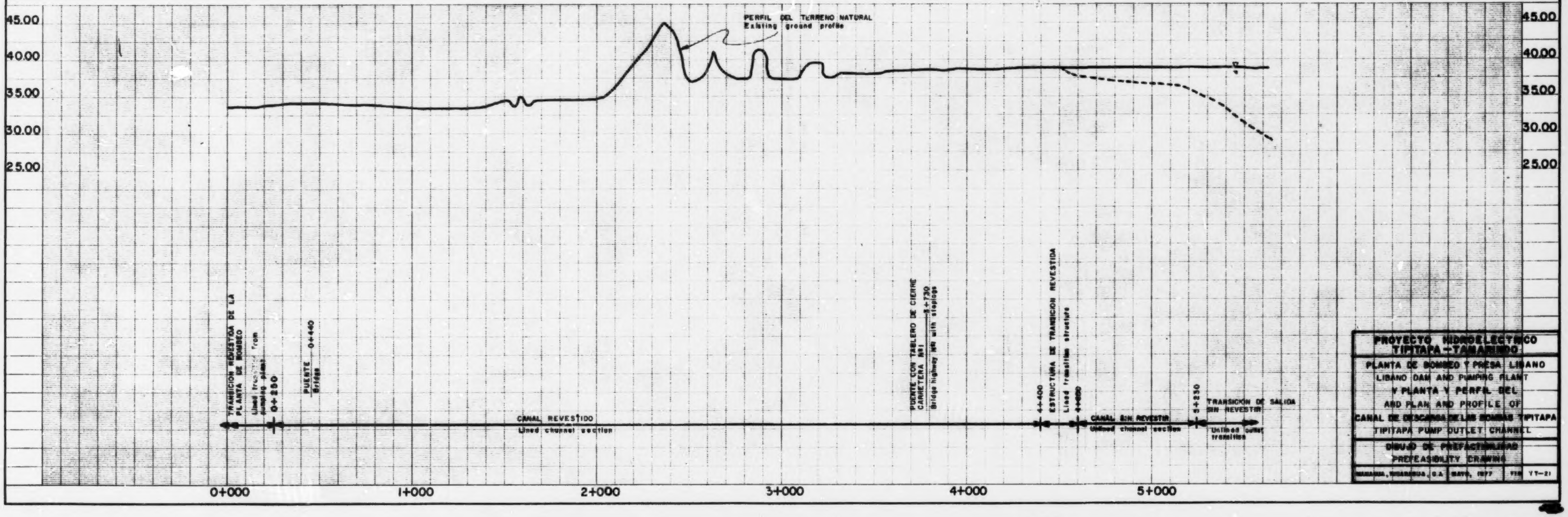
DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A. MAYO, 1977 FIG TT-20

PLAN
NOTE BOOK
No.

PROFILE
NOTE BOOK
No.


℄ CANAL DE DESCARGA DEL VENTEDERO
℄ Spillway outlet channel
1+000
2+000
3+000
4+000
5+000
1348000 N
1348.000 N
1349000 N
1349.000 N
VIENE DE LA FIGURA TT-20
Match to figure TT-20
CRESTA DEL VERTEDERO
Spillway crest
El 39.4
PLANTA DE BOMBEO LIBANO
Libano pumping plant
PUENTE
Bridge
EL LIBANO
TIPITAPA
℄ CANAL DE DESCARGA DE BOMBA
℄ Tipitapa pump outlet channel
LA BOCANA
PUENTE CON TABLERO PARA CIERRE DEL CANAL
Bridge with stoplogs for channel closure
LAGO DE MANAGUA
LEVANTAR EL CAMINO EXISTENTE PARA FORMAR UN DIQUE
Raise existing road to form dike
602.000 E
601.000 E
600.000 E
599.000 E
598.000 E
597.000 E
PLANTA
Plan
CAMINO EXISTENTE RELOCALIZADO
Relocated existing road
CARRETERA Nº1 EXISTENTE (PANAMERICANA)
Existing highway Nº1 (Pan American)
0
500
1000mts
ESCALA EN METROS


45.00
40.00
35.00
30.00
25.00
PERFIL DEL TERRENO NATURAL
Existing ground profile
TRANSICION REVESTIDA DE LA PLANTA DE BOMBEO
Lined transition from pumping plant
0+250
PUENTE 0+440
Bridge
CANAL REVESTIDO
Lined channel section
PUENTE CON TABLERO DE CIERRE CARRETERA Nº1 3+730
Bridge highway Nº1 with stoplogs
4+400
ESTRUCTURA DE TRANSICION REVESTIDA
Lined transition structure
4+600
CANAL SIN REVESTIR
Unlined channel section
5+230
TRANSICION DE SALIDA SIN REVESTIR
Unlined outlet transition
0+000
1+000
2+000
3+000
4+000
5+000

PROYECTO HIDROELECTRICO
TIPITAPA - TAMARINDO

PLANTA DE BOMBEO Y PRESA LIBANO
LIBANO DAM AND PUMPING PLANT
Y PLANTA Y PERFIL DEL
AND PLAN AND PROFILE OF
CANAL DE DESCARGA DE LAS BOMBAS TIPITAPA
TIPITAPA PUMP OUTLET CHANNEL

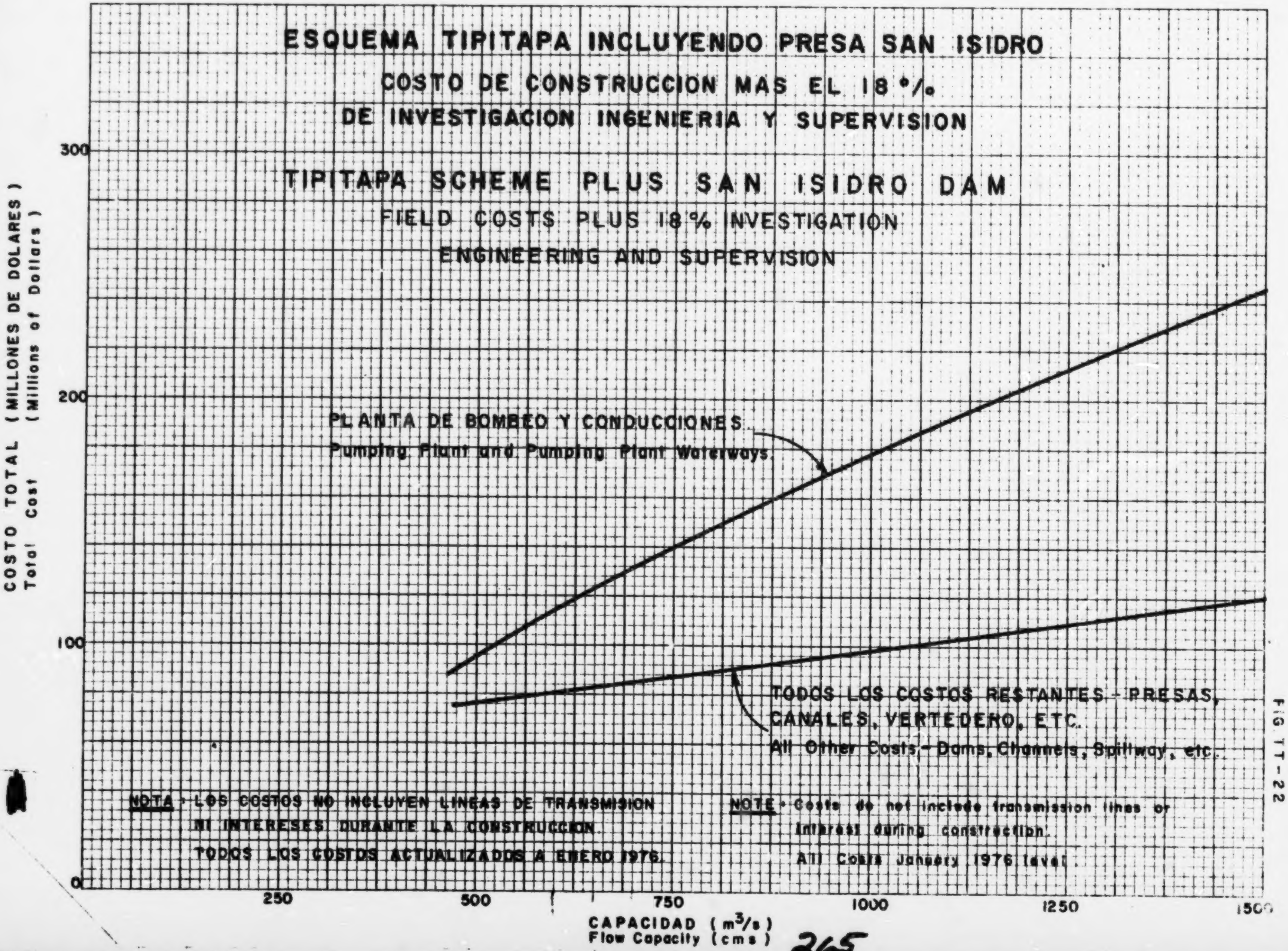
DIBUJO DE PREFACTIBILIDAD
PREFEASIBILITY DRAWING

MANAGUA, NICARAGUA, C.A.	MAYO, 1977	FIG.	YT-21

263

264

K•E 5 X 5 TO THE CENTIMETER 18 X 24 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1610



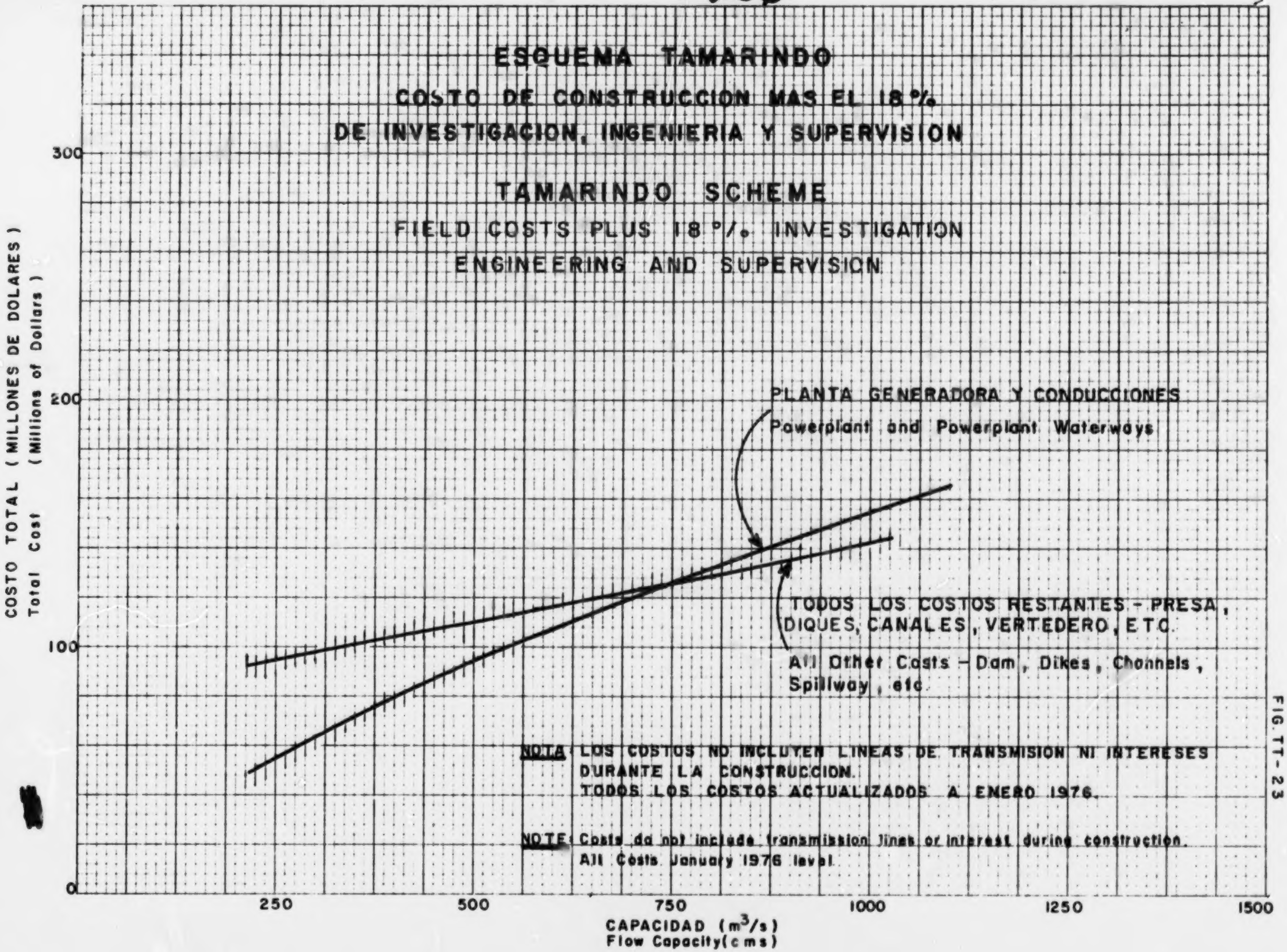
ESQUEMA TIPITAPA INCLUYENDO PRESA SAN ISIDRO
COSTO DE CONSTRUCCION MAS EL 18 %
DE INVESTIGACION INGENIERIA Y SUPERVISION

TIPITAPA SCHEME PLUS SAN ISIDRO DAM
FIELD COSTS PLUS 18 % INVESTIGATION
ENGINEERING AND SUPERVISION

NOTA - LOS COSTOS NO INCLUYEN LINEAS DE TRANSMISION NI INTERESES DURANTE LA CONSTRUCCION.
TODOS LOS COSTOS ACTUALIZADOS A ENERO 1976.

NOTE - Costs do not include transmission lines or interest during construction.
All Costs January 1976 level.

FIG. TT-22



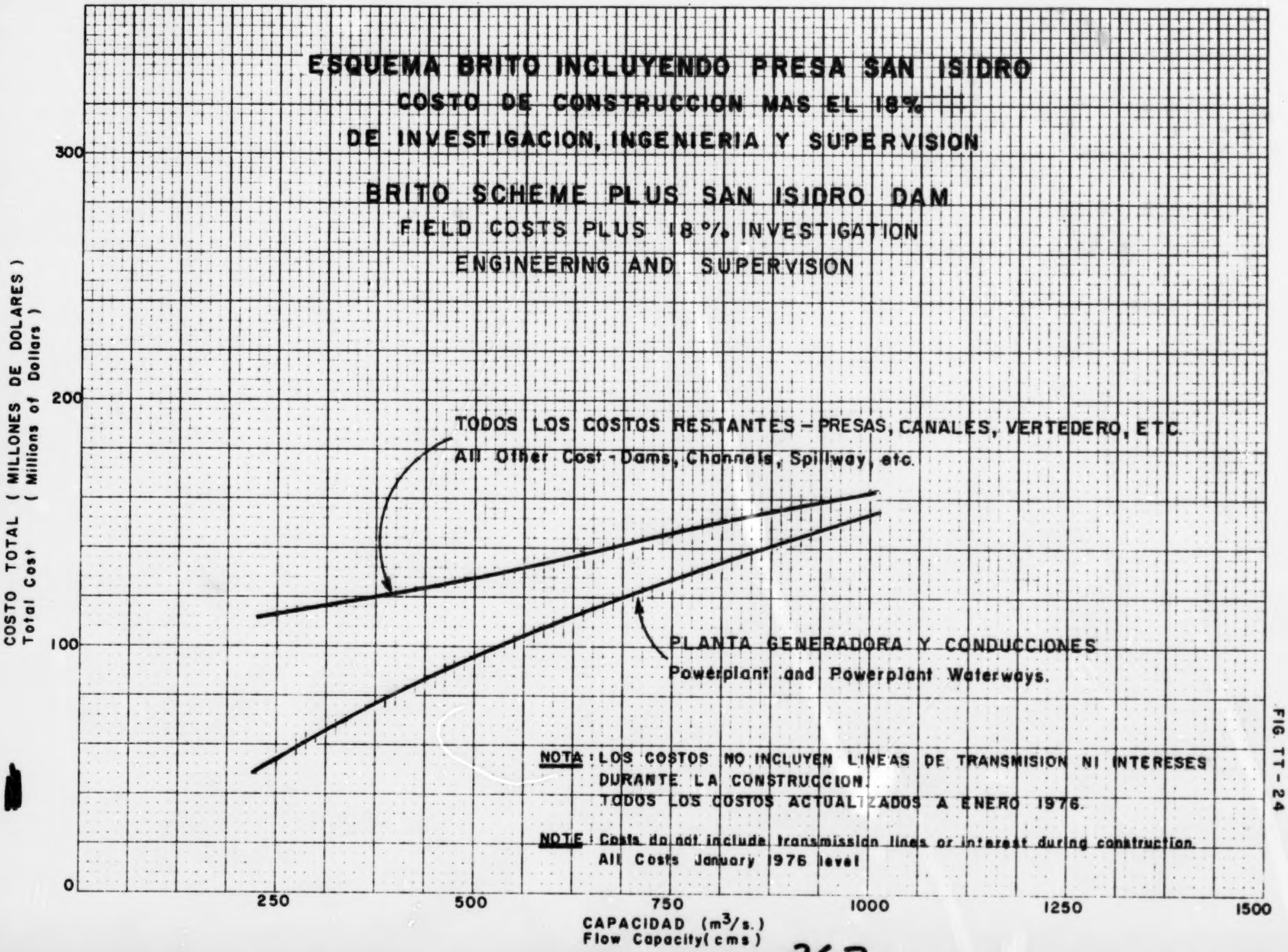
ESQUEMA TAMARINDO
COSTO DE CONSTRUCCION MAS EL 18 % DE INVESTIGACION, INGENIERIA Y SUPERVISION

TAMARINDO SCHEME
FIELD COSTS PLUS 18 % INVESTIGATION ENGINEERING AND SUPERVISION

NOTA: LOS COSTOS NO INCLUYEN LINEAS DE TRANSMISION NI INTERESES DURANTE LA CONSTRUCCION.
TODOS LOS COSTOS ACTUALIZADOS A ENERO 1976.

NOTE: Costs do not include transmission lines or interest during construction.
All Costs January 1976 level.

FIG. TT-23



ESQUEMA BRITO INCLUYENDO PRESA SAN ISIDRO
COSTO DE CONSTRUCCION MAS EL 18%
DE INVESTIGACION, INGENIERIA Y SUPERVISION

BRITO SCHEME PLUS SAN ISIDRO DAM
FIELD COSTS PLUS 18% INVESTIGATION
ENGINEERING AND SUPERVISION

NOTA: LOS COSTOS NO INCLUYEN LINEAS DE TRANSMISION NI INTERESES DURANTE LA CONSTRUCCION.
TODOS LOS COSTOS ACTUALIZADOS A ENERO 1976.

NOTE: Costs do not include transmission lines or interest during construction.
All Costs January 1976 level

FIG. TT-24

TIPITAPA-TAMARINDO PROJECT

POWER AND ECONOMICS MEMORANDUM

Two alternative plans were considered for development of the Lake Nicaragua and Lake Managua power potential. These are (1) Brito Dam and Powerplant and (2) Tamarindo Dam and Powerplant with a pumping station located at Tipitapa.

Power Capability Studies

Energy Production

Twenty-one-year water operation studies were run for the reservoir, covering the period 1930-1931 to 1949-1950. Releases were regulated to maintain water surface of the reservoir (Lake Nicaragua) at elevations 33.0 and 31.5 meters above mean sea level, to minimize spills, and to maintain power output as high as practical. An average flow of 500 m^3/s was used for the computation of the annual average energy production.

Since water surface fluctuates only a maximum of 1.5 meters, power capability remains nearly constant. The average annual generation at Brito would be 1138 GWh, assuming a head of 31.5 meters and an 84.2 percent efficiency. The average annual generation at Tamarindo would be 1355 GWh, assuming a head of 37.5 meters and an 84.2 percent efficiency.

The pumping station at Tipitapa would consist of ten 7-MW units, the energy necessary to pump a flow of 500 m^3/s was estimated at 394 GWh per year, assuming a head of 7.5 meters and an 82 percent efficiency.

The net average annual production at Tamarindo would be 961 GWh.

This energy is expected to be available in July 1983 for Brito and July 1984 for Tipitapa-Tamarindo. At that time it could be used immediately to meet the growing demand. The generation was unable to meet the demand growth for the 4 years after the initiation of the operations.

Powerplant Sizing

An incremental analysis was conducted to determine the most economically efficient capacity of the two powerplants. Sizing Brito and Tipitapa-Tamarindo Powerplants was done on the basis of reconnaissance cost estimates and preliminary 21-year operation studies over the period 1930-1950. Three sizes of plants were analyzed for each plan: 165, 190, and 260 MW at Brito; 200, 235, and 320 MW at Tamarindo.

The amount of annual energy produced at each plant remains constant regardless of plant capacity within the ranges studied. Therefore, the analysis was limited to a determination of whether it would be economical to add peaking capacity to the plants.

By adding capacity, plant factor was reduced from approximately 80 percent to 68 percent for the midrange capacity and to 50 percent for the highest capacity.

Average power production possible at each plant was estimated based on the average annual production in the 21-year operation study. Energy was calculated for each plant from the operation study.

Benefits for energy and minimum capacity were based on the cost of the most likely thermal alternative which would be a 100-MW oil-fired baseload plant with a 60 percent plant factor. The annual costs of such a plant recently installed in Nicaragua were $70.98 per kW for capacity and $0.0258/kWh for energy (table E-1). The benefits for added capacity in the larger plant sizes were based only on the annual capacity cost of $21.86 per kW for a gas turbine plant in Nicaragua which is the most likely alternative source of peaking capacity (table E-2). Estimates of the amount of peaking energy which could be produced were not available. Therefore, the energy value was held constant at $0.0258/kWh for all plant sizes based on the variable costs of the oil-fired steamplant. The incremental cost of powerplant, switchyard, and transmission was estimated for each plant size.

Summaries of the present worth of benefits and costs for the different plant sizes are shown in the following tabulations, using a 9 percent interest rate:

Brito
($ million)

	165 MW	190 MW	260 MW
Benefits	450.2	456.2	473.0
Costs	312.5	332.1	384.0
Difference	137.7	124.1	89.0

The difference between benefits and costs is at a maximum for 165 MW, five 33-MW units. This means that for a lower plant factor, the hydro investment cost is too high and not the best alternative to add capacity to the system; for this reason, 165 MW was the size selected. Average plant factor would be 78.7 percent.

Tamarindo
($ million)

	200 MW	235 MW	320 MW
Benefits	372.9	400.8	421.1
Costs	527.8	593.9	708.5
Difference	-154.9	-193.1	-287.4

Costs exceed benefits over the entire range of plant capacities. An installed capacity of 200 MW, five 40-MW units, was selected as the point of minimizing the amount by which costs exceed benefits. The average plant factor would be 77 percent.

Cost Analysis

The following cost analysis is for a single purpose power development at each of the two sites.

Table E-1. - Costs of new oil-fired steam-electric generating plant
100 MW; 60% P.F., 25-yr life, $16.10/bbl oil

	Plant		Substation		Transmission		Total
	%	$/kW	%	$/kW	%	$/kW	$/kW
A. Plant investment		360		32		35	
B. Annual capacity cost							
1. Fixed charges							
a. Cost of money	9.00		9.00		9.00		
b. Depreciation	1.18		1.18		0.12		
c. Interim replacements	0.35		0.35		0.10		
d. Insurance	0.25		0.25		0.25		
e. Taxes	-		-		-		
Total fixed charges	10.78	38.81	10.78	3.45	9.47	3.31	45.57
2. Carrying cost of fuel inventory							2.19
3. Fixed operating costs							
a. Fuel - 10% of annual		14.80					
b. Operation and maintenance		4.67	1.90	0.61		0.15	
c. Administration and general expense		2.80		0.15		0.04	
Total fixed operating costs		22.27		0.76		0.19	23.22
Total annual capacity costs							70.98
C. Energy - variable operating cost							c/kWh
a. Energy fuel (11,000-1,100) Btu							2.53
b. Operation and maintenance							0.05
Total energy cost							2.58

Table E-2. - Cost of gas turbine peaking plant
20-year life, 10% avg. P.F., 15 MW, $29.48/bbl oil

A. Plant investment		$ 111
B. Annual capacity cost		
1. Fixed charges	%	$/kW
a. Cost of money	9.00	
b. Depreciation	1.95	
c. Interim replacement	0.35	
d. Insurance	0.25	
d. Taxes	-	
Total fixed charges	11.55	12.82
2. Carrying cost of fuel inventory		
3. Fixed operating costs		
a. Fuel - 10% of annual	-	-
b. Operation and maintenance		-
c. Administration and general expense		1.09
Total fixed operating costs		1.09
Total annual capacity costs		14.25
C. Energy - variable operating costs		c/kWh
a. Energy fuel 13 092 Btu/kWh		6.50
b. Operation and maintenance		0.50
Energy cost - variable		7.30

Construction Costs

It is estimated that powerplant, waterways, dams, channels, and spillways will cost $240.1 million at Brito. The costs of the pumping station at Tipitapa and the powerplant, dams, channels, waterways, and spillway at Tamarindo were estimated to be $404.0 million. These costs include materials, construction, administration, general expenses, and a factor of 15 to 20 percent for contingencies.

Transmission Construction Costs

The fact that both powerplants and the pumping station are located near the load centers considerably reduced transmission costs. Two 230-kV lines from Brito to Masaya Substation were estimated to cost $15 million. A comparative system for Tamarindo would be two 230-kV lines to the Nicaragua Powerplant-Leon existing line; the pumping station at Tipitapa would be connected to the Tipitapa-Boaco existing line; both were estimated to cost $12 million.

Interest During Construction

The period of analysis used in this report is 50 years after the first units are in operation, assumed to be July 1983 for Brito and July 1984 for Tipitapa-Tamarindo. Interest during construction at 9 percent simple interest for the years prior to operation would amount to $47.1 million for Brito and $99.3 million for Tipitapa-Tamarindo.

Total investment to be amortized would be $302.2 million and $515.3 million for Brito and Tipitapa-Tamarindo, respectively.

Annual Operation, Maintenance, and Replacement Costs

Estimates of annual operation, maintenance, and replacement used in this report are based on experience in operating hydroelectric projects in Nicaragua. Annual operation and maintenance costs would be constant beginning with the first year of operation. Replacement of units of property would be made periodically according to their life spans; however, for analysis, these costs have been reduced to present worth and are spread over the 50-year project life as annual equivalent costs.

Administration and general costs have been estimated as 20 percent of O&M costs. Table E-3 gives summaries of the estimated total average annual costs over the period of analysis for Brito and Tipitapa-Tamarindo.

Table E-3. - Annual costs
U.S. Dollars

	Investment	OM&R	Total
Brito	27,560,640	940,500	28,501,140
Tipitapa-Tamarindo	46,995,410	1,140,000	48,135,410

Construction Schedule

To aid in the economic analysis of the Tipitapa-Tamarindo Scheme as well as the Brito alternative, a very tentative construction schedule is shown in table TT-6 (Designs and Estimates chapter). This indicates the annual progress which would be possible on each scheme if no unusual delays occurred and also the annual schedule of project cost appropriations. The final dates of July 1984 for the Tipitapa-Tamarindo Scheme and July 1983 for the Brito Scheme obviously depend upon the emphasis placed on project completion and the availability of construction money.

Project Benefits

Benefits From Energy

In order to determine the benefits that the project will offer by the generation of energy, the usual method of considering costs of capacity and energy of the most probable alternative thermal plant, as the best estimate of the value of hydroelectric power, was used in this appraisal study. The most likely alternative is a 100-MW oil-fired baseload steamplant with a 60 percent plant factor. Base costs were computed for the last oil-fired steamplant built in Nicaragua, as shown in table E-1.

Using the values of the steamplant and the results of energy and capacity estimated by operations studies, power benefits were computed giving the results shown in table E-4.

Table E-4. - Annual benefits
U.S. Dollars

Brito	
Energy benefit (1138 GWh)	29,360,400
Capacity benefits (165 MW)	11,711,700
Total annual benefits	41,072,100
Tipitapa-Tamarindo	
Energy benefits (961 GWh)a/	24,793,800
Capacity benefits (130 MW)a/	9,227,400
Total annual benefits	34,021,200

a/ Net increase in energy and capacity after subtracting energy and capacity used by the Tipitapa Pumping Plant.

Other Benefits

If a hydroelectric plant were constructed, the country would gain savings in foreign exchange due to the reduction of fuel imports. These savings would grow as the price of fuel rises in the international market. At the 1976 fuel price, these savings would amount to $28.8 million if the plant were built at Brito and $24.3 million if it were built at Tamarindo. The project would also reduce dependence on petroleum as a source of energy.

The Tipitapa-Tamarindo Scheme would produce other benefits such as making water available for future irrigation of agricultural lands around Lake Managua, future supplies for the city of Managua, and reclamation of the quality of Lake Managua by diluting its high mineral content. The clean lake also would stimulate the development of recreational centers for boating, sport fishing, etc. These benefits were not computed at this stage of the study, but they should be at the next stage. The Brito Scheme could also be modified to include provisions for reclaiming Lake Managua. This alternative should also be examined during the feasibility study.

Economic Analysis

The economic justification of a project is determined by a comparison of its costs and benefits. These costs and benefits occur over a period of time and must be related to each other on some common time basis. The procedures used in this report are to bring all benefits and costs to a common point taken as the beginning of operations. Interest during construction is estimated as simple interest of 9 percent on each year's investment until the first units are in service, assumed to be July 1983 for Brito and July 1984 for Tipitapa-Tamarindo.

The analysis was made over a period of 50 years, using a 9 percent interest rate. This rate was considered as the most probable cost of borrowing from international lending agencies in the coming years.

This analysis assumes the projects are for electrical energy generation exclusively. The usual evaluation indicators were calculated, net present value, benefit-cost ratio, and internal rate of return.

The total benefits for Brito in the year 1983 have a present value of $450.2 million, and the present value of total costs is $312.5 million. Capitalized benefits exceed costs in the amount of $137.7 million.

For Tipitapa-Tamarindo, the total power benefits in the year 1984 have a present value of $372.9 million and the total costs a value of $527.8 million. Costs exceed benefits in the amount of $154.9 million.

The benefit-cost ratio is 1.44 for Brito and 0.70 for Tipitapa-Tamarindo.

The internal rate of return, the discount rate that results in costs equal to benefits, is 12.5 percent for Brito and 6.5 percent for Tipitapa-Tamarindo.

Tables E-5 and E-6 summarize the results of the economic analysis.

In conclusion, this reconnaissance analysis indicates that a single purpose hydroelectric powerplant is economically justified at the Brito site but not at the Tamarindo site. As mentioned earlier, this analysis does not include an evaluation of the benefits resulting from various alternative multipurpose developments. Also, it does not include other potential benefits such as a hydro capacity value adjustment reflecting the greater dependability, versatility, and more desirable operating characteristics of hydropower, employment of unemployed and underemployed resources in project construction, and the potentially higher value of peaking energy. Therefore, this appraisal study indicates the desirability of a detailed feasibility grade investigation to determine the most acceptable plan of development.

Table E-5. - Summary of economic analysis - Brito
discount rate - 9 percent
Values in million dollars

						Present worth			
Year	Investment	IDC	OM&R	Power benefits	Inv.	IDC	OM&R	Total cost	Benefits
1	51.0	16.1							
2	76.5	17.2							
3	89.3	12.1							
4	38.3	47.1							
1983-2032			0.94	41.07	255.1	47.1	10.3	312.5	450.2

Benefit-cost ratio: 1.44
Net present worth: $137.7
Internal rate of return: 12.5 percent

Computation of Internal Rate of Return

Interest rate (%)	Benefits $ millions	Costs $ millions	Difference $ millions
12	341.1	325.7	15.4
13	315.2	330.3	-15.1
		Interval	30.5

Interpolation: $\frac{15.4}{30.5} = 0.505$

Internal rate of return = 12 + 0.5 = 12.5 percent

Table E-6. - Summary of economic analysis - Tipitapa-Tamarindo
Discount rate - 9 percent
Values in million dollars

						Present worth			
Year	Investment	IDC	OM&R	Power benefits	Inv.	IDC	OM&R	Total cost	Benefits
1	83.2	33.7							
2	83.2	26.2							
3	104.0	23.4							
4	104.0	14.1							
5	41.6	1.9							
1984-2033			1.14	34.0	416.0	99.3	12.5	527.8	372.9

Benefit-cost ratio: 0.70
Net present worth: $-154.9
Internal rate of return: 7.2 percent

Computation of Internal Rate of Return

Interest rate (%)	Benefits $ millions	Costs $ millions	Difference $ millions
6	535.9	500.2	35.7
7	469.2	508.9	-39.7
		Interval	75.4

Interpolation: $\frac{35.7}{75.4} = 0.473$

Internal rate of return = 6 + 0.5 = 6.5 percent

TIPITAPA-TAMARINDO PROJECT

IRRIGATION MEMORANDUM

If the Tipitapa-Tamarindo Project were built, the water from Lake Managua could be used for irrigation of the agricultural lands around Lake Managua and the northern end of Lake Nicaragua. Over 90 percent of the country's irrigable land, or about 1 107 000 hectares, is located in this region. This region is one of the most important agricultural centers of the country. It is cultivated with cotton, rice, sorghum, sugarcane, beans, etc. However, the production (yield) is subject to the availability of rainfall during the rainy season. If the rainfall is not well distributed or if a drought occurs, the yield is reduced or evan lost.

Due to the preliminary character of this study, only the land below 50 meters of elevation was considered for potential irrigation. This would amount to 200 000 hectares. It was assumed that it would require a 10-year period for full development of this area.

The irrigation project would start operating 4 years after the hydroelectric project begins operating. This period is necessary to permit the desalination of Lake Managua, estimated in 2 years, and to permit the construction of the main works for irrigation.

Project Costs

Preliminary costs were estimated for the canals and pumps needed to irrigate the 200 000 hectares considered in this project. They would amount to $92 million, as of 1976. A very tentative construction schedule is shown in table I-1, which indicates the annual schedule of project cost appropriations. Potential drainage construction costs were not estimated. The operation and maintenance costs were estimated to be $920,000 a year. The project life was estimated to be 25 years and no provision was made for replacement of units.

The costs for the power function are the same as shown in table E-6, Power and Economics Memorandum. They amount to $390.5 million for construction, $93.2 million for interest during construction, and $1.14 million a year for OM&R. The present value of these costs, using a 9 percent interest rate, amounts to $496.2 million.

The annual costs for the Tipitapa-Tamarindo Project, with irrigation, are shown in table I-2.

Table I-1. - Construction cost schedule

Year	Percent	$ million
1985	10	9.2
1986	10	9.2
1987	15	13.8
1988	15	13.8
1989	15	13.8
1990	15	13.8
1991	5	4.6
1992	5	4.6
1993	5	4.6
1994	5	4.6
Total	100	92.0

Table 1-2. - Tipitapa-Tamarindo Project
Annual costs (9 percent)

	$ Million
Power	
Investment	44 126 436
OM&R	1 140 000
Total	45 266 436
Irrigation	
Investment	9 366 175
O&M	920 000
Total	10 286 175

Project Benefits

To obtain the irrigation benefits, the annual production per hectare, with and without irrigation, was calculated. The average annual production obtained in the country for the different crops was multiplied by the number of hectares that are going to be irrigated each year. The difference between the production with and without irrigation was computed as the annual benefits. No consideration was made for the different production costs, as no data were available. So these benefits must be considered as a very rough measure of the real project's benefits that must be computed as the increase in the net farm income. This must be completed in the feasibility study. After the tenth year, when the total land (200 000 hectares) will be irrigated, the benefits were considered constant until the end of the project life, estimated in 25 years.

It was assumed that the present structure of the crops would not change during the first 5 years of the project life. However, it was considered that since the first year there would be two yields in the lands dedicated to the culture of basic grains (rice, beans, corn, sorghum, etc), and one additional crop of basic grains in the lands dedicated to cotton.

From the average annual flow of 500 m^3/s available were subtracted 90 m^3/s estimated to be the flow necessary to irrigate 200 000 hectares.

The amount of average annual energy production was then calculated with this net flow of 410 m^3/s. It would be 1111 GWh per year once the irrigation project starts operating.

The average energy required to run the pumping station at Tipitapa would be 394 GWh per year.

The annual average energy necessary for the operation of the irrigation pumps would be 70 GWh. The net energy produced would amount to 647 GWh per year.

The annual benefits for power amount to $35.8 million for the first 4 years and to $27.7 million afterwards.

Economic Analysis

The preliminary costs and benefits for the irrigation purpose were added to the costs and benefits of the power function for the evaluation of the Tipitapa-Tamarindo Project.

All the costs and benefits are expressed in terms of their present value in July 1984, the assumed date for the initiation of operations of the hydroelectric project. A 9 percent interest rate was used in these computations. The total costs have a present value of $565.32 million, and the total benefits a present value of $828.83 million. Capitalized benefits exceed costs in the amount of $263.51 million.

The benefit-cost ratio is 1.47.

The internal rate of return, the discount rate that results in costs equal to benefits, is 12 percent.

Table I-3 summarizes the results of the economic analysis of the Tipitapa-Tamarindo Project with irrigation.

Conclusions and Recommendations

Both the benefit and cost estimates for irrigation service are extremely rough and preliminary. It is likely that costs are underestimated and benefits are overestimated. Therefore, the results of the benefit-cost analysis should be interpreted only as an indication that irrigation development is potentially justifiable economically and that this function should be evaluated more thoroughly in a feasibility study.

Table I-3. - Economic Analysis
Tipitapa-Tamarindo Power and Irrigation Project
(9 percent - $ millions)

	Construction		IDC	OM&R		Benefits		Present value				
Year	Power	Irrigation	Power	Power	Irrigation	Power	Irrigation	Construction	IDC	OM&R	Total costs	Total benefits
-1	78.1		31.6									
-2	78.1		24.6									
-3	97.6		22.0									
-4	97.6		13.2									
0	39.1		1.8	1.14	-	35.8	-	453.22	93.2	18.9	565.32	828.83
1		9.2		1.14	-	35.8	-					
2		9.2		1.14	-	35.8	-					
3		13.8		1.14	-	35.8	-					
4		13.8		1.14	0.92	27.7	5.97					
5		13.8		1.14	0.92	27.7	10.91					
6		13.8		1.14	0.92	27.7	16.14					
7		4.6		1.14	0.92	27.7	20.46					
8		4.6		1.14	0.92	27.7	30.51					
9		4.6		1.14	0.92	27.7	43.13					
10		4.6		1.14	0.92	27.7	58.20					
11				1.14	0.92	27.7	79.69					
12				1.14	0.92	27.7	105.10					
13				1.14	0.92	27.7	125.01					
14				1.14	0.92	27.7	125.01					
15				1.14	0.92	27.7	125.01					
16				1.14	0.92	27.7	125.01					
17				1.14	0.92	27.7	125.01					
18				1.14	0.92	27.7	125.01					
19				1.14	0.92	27.7	125.01					
20				1.14	0.92	27.7	125.01					
21				1.14	0.92	27.7	125.01					
22				1.14	0.92	27.7	125.01					
23				1.14	0.92	27.7	125.01					
24				1.14	0.92	27.7	125.01					
25				1.14	0.92	27.7	125.01					

Table I-3. - Economic Analysis - (Continued)

Year	Construction		IDC	OM&R		Benefits		Present value				
	Power	Irrigation	Power	Power	Irrigation	Power	Irrigation	Construction	IDC	OM&R	Total costs	Total benefits
26				1.14	0.92	27.7	125.01					
27				1.14	0.92	27.7	125.01					
28				1.14	0.92	27.7	125.01					
29				1.14		27.7						
30				1.14		27.7						
31				1.14		27.7						
32				1.14		27.7						
33				1.14		27.7						
34				1.14		27.7						
35				1.14		27.7						
36				1.14		27.7						
37				1.14		27.7						
38				1.14		27.7						
39				1.14		27.7						
40				1.14		27.7						
41				1.14		27.7						
42				1.14		27.7						
43				1.14		27.7						
44				1.14		27.7						
45				1.14		27.7						
46				1.14		27.7						
47				1.14		27.7						
48				1.14		27.7						
49				1.14		27.7						

B/C = 1.47:1.
NPV = $263.51 million.
Internal rate of return = 12 percent.

Computation Internal Rate of Return

Interest rate	Benefits $ millions	Costs $ millions	Difference $ millions
11	647.95	572.81	75.14
12	578.36	580.12	-1.81
		Interval	76.95

Interpolation: $\frac{75.14}{76.95} = 0.9764$

Internal rate of return: 11 + 1 0 = 12.0 percent.

SOCIAL AND ENVIRONMENTAL ASPECTS

1. Socioeconomic Setting

In 1974, the total population of Nicaragua was 2,086,691 with 994,733 in urban areas and 1,091,958 rural. The annual population growth rate between 1970 and 1975 was 3.3 percent. For Central America as a whole, the growth rate for the same period was 3.2 percent. Nicaragua is essentially agricultural, although industrialization is taking place at a rapid rate. The principal urban area in Nicaragua is Managua (400,000).

The Republic of Nicaragua became independent in 1838. It has a constitutional government, a two-chamber legislature, and an elected president. Nicaragua is the largest in area of the Central American republics and the most thinly populated. About 80 percent of the population lives in the area between the great lakes and the Pacific. The people of the western half are principally of mixed Spanish and Indian extraction with some pure Spanish and Indians. The population of the Caribbean slope is largely composed of Indians, Zambos, and Negroes from Jamaica and other Caribbean Islands. Spanish is the language of the country and the prevailing religion is Catholic, although it is not official. Elementary school instruction is provided both by public and private systems and there are three universities, one in Leon and two in Managua. The National Guard functions as a police force and army.

Agriculture is the principal industry with the most important crops being cotton, coffee, sugar cane, cocoa, maize, sesame, and beans, a large proportion of which is exported. In addition to these crops, sorghum, rice, wheat, plantains, cassava (yucca), and many tropical fruits are grown and largely consumed locally. Cattle raising is also an important activity.

The Nicaraguan social structure has been essentially colonial in nature, i.e., a small group of wealthy landed families at the top and a broad peasant class at the bottom. A high proportion of the latter class did not own land or were squatters on what could be termed the public domain. The squatter problem is being resolved to some extent by an intensive program combining resettlement on open or acquired lands and assigning ownership to present settlers on lands in government ownership. About 32 percent of the farm workers, however, still do not own land. Less than 1 percent of the farmers account for 41.2 percent of the total farmland ownership.

About 30 percent of the total land is in farms. Intensively cultivated land for such crops as coffee and cotton account for 20 percent of the farmland and extensive use, which is primarily for pasture, makes up the balance.

Industry is largely concerned with processing agricultural products, manufacturing light consumer goods, or fuel processing. Lumber and plywood are also important manufacturing elements.

The gross national product (GNP) in 1973 for Nicaragua was 442 Current Central American Pesos. The annual growth in GNP has averaged over

5 percent since 1968. In 1974 about 1 percent of the population or 27,000 people were employed in industry. An indication of the growing importance of industry in Nicaragua is the 43 percent increase in exports of industrial products between 1970 and 1974.

The only avenue of transportation below San Carlos, Nicaragua, is the San Juan River and its tributaries. No roads exist near the river in Nicaragua and the road into San Carlos is impassable during the rainy season. On the Costa Rican side, a road comes down to the port on the Frio River (Los Chiles). Costa Rica by treaty has full rights of navigation on the San Juan River.

Five major rapids are in the vicinity of El Castillo, the most difficult of which is located at El Castillo. On the San Juan River the size of the barges and tugboats is limited by the depth of water over the rapids.

A number of vessels ply between Granada and San Carlos and other points on Lake Nicaragua following a regular schedule. Nicaraguan boats travel between San Carlos and San Juan del Norte carrying both passengers and cargo with emphasis on cargo. Four leave San Carlos weekly and one leaves every 2 weeks.

Costa Rica reported two companies operating on the San Juan River and its tributaries including the Frio River with a total of five tugboats and nine barges carrying both passengers and cargo.

Air transport is common throughout the country although regularly scheduled passenger and freight routes are limited. Airstrips for small aircraft are numerous although frequently poorly maintained and without services.

Rail transportation is available between Granada and the harbor of Corinto via Managua and Leon with service to Puerto Somoza, Malpaisillo, and Rio Grande.

The timber industry is important in Nicaragua and in 1974 the total value of products was 145 million cordobas of which nearly 99 million was from plywood manufacture. There is a large plywood concession in the Departmento Rio San Juan below the Chiripo River and an important plywood plant (Plynica) at San Juan on the Tipitapa River.

Nicaragua has a relatively low consumption rate of fish products. The annual per capita consumption of fish is about 2.18 kg compared to 14 kg for beef. Freshwater fish accounts for 23 percent of the total fish consumed.

Lake Nicaragua has an annual fish yield of about 0.5 lb/acre (0.56 kg/ha) while the equivalent yield from Lake Managua is about 4.3 lb/acre (4.8 kg/ha) (Cole, 1976).

Estimates of catch for Lake Nicaragua range from about 260,000 to over 1,000,000 kg per year. The sawfish in 1974 was estimated to have produced about 230,000 kg of processed meat.

Lake Nicaragua has about 500 fisherman of which 305 are full time and 195 part time. About half fish in the Isletas de Granada or around Omotepe Island. The part-time fishermen operate only during the dry season and fish mainly for gaspar.

In 1974, the average weekly income of the fishermen on Lake Nicaragua was estimated to be between C$150 and C$300. Gaspar fishermen's income was slightly higher, being C$250 to C$400 per week (U.S. $1.00 = C$7.00).

Subsistence fishing occurs in the Tamarindo River drainage and estuary although some shellfish and freshwater shrimp are marketed from the estuarine area.

Lake Managua supports a smaller number of commercial fishermen whose catch is consumed locally and does not reach the markets in Managua or Granada. Most of the catch consists of guapote and maojarra.

Fishing on the San Juan River and its tributaries is for subsistence or local consumption except for the gaspar, shark, and sawfish taken at the outlet on Lake Nicaragua.

The fisheries in the estuarine area of the San Juan River, except for the sport fishing industry at Barra del Colorado in Costa Rica, are for subsidence or local use.

Nicaragua is in the midst of a malaria epidemic. In 1972 there were 3,000 cases nationally; in 1975 about 45,000; in 1976 the estimate is 60,000; and the total is expected to reach 80,000 before new controls can begin to take effect. The epidemic area seems to be mostly in western Nicaragua.

Water-associated vectors are present in the San Juan River which can carry shistosomiasis (snail), onchocerciasis (blackfly), yellow fever (mosquito), and filariasis (mosquito). All of these diseases occur in Nicaragua or neighboring Central American or Caribbean countries, although none of them have apparently been verified from the project area.

An important disease, essentially a problem of sanitation, is gastroenteritis, a debilitating and sometimes fatal disease of adults and frequently fatal disease of children and infants, which is a countrywide problem. Lake Managua has raw sewage flowing in from the city of Managua and open drainage channels taking street runoff and uncontrolled sewage directly into the lake. Municipal sewage finds its way directly or indirectly into Lake Nicaragua from the various communities along its shores. At San Carlos, for instance, outhouses are placed on stilts over the river wherever residences back up to the water. Water supplies outside the Managua area are frequently poorly treated and controlled.

2. Environmental Setting

The San Juan River Basin is the largest watershed in Nicaragua with a total drainage above its mouth on the Atlantic Coast of approximately 40,000 km^2. The longest watercourse of the basin is over 640 km long, extending from the headwaters of the Viejo River in northwestern Nicaragua through Lakes Managua and Nicaragua, thence through the San Juan River to its several outlets on the Atlantic on the east coast of Nicaragua and Costa Rica.

The San Juan River watershed can be divided into three parts: Lake Managua and its tributaries, Lake Nicaragua and its tributaries, and the San Juan River itself from its origin at San Carlos on Lake Nicaragua to its delta in the Atlantic Ocean.

The drainage area of Lake Managua is approximately 5,819 km^2. The lake itself has a surface area of 1,016 km^2 and an average depth of 8.8 m. Numerous tributaries flow into the lake, the largest of which is the Rio Viejo. Other important tributaries are the Sinecapa River and the Pacora River. The normal lake level is 39 m above mean sea level and it has been known to be as low as 37.6 m and as high as 43.4 m. Inflow into Lake Managua is about balanced with losses due to evaporation and irrigation diversions on tributary streams.

Lake Managua has no extensive swamps. The shoreline is either in crops or tropical savanna, which is grazed. There is some broadleaf evergreen forest in patches where moisture is high or terrain is favorable. Most remaining forest, however, is xerophytic.

The water quality of Lake Managua is very poor both from natural causes and municipal and industrial pollution, principally from the city of Managua. Heavy use of insecticides in the agricultural areas is also said to have caused pollution.

The Tamarindo River is a small nearly intermittent stream in the southwestern part of Departmento Leon which enters the Pacific Ocean at Puerto Somoza. It has a drainage area above tidewater of about 210 km^2. The village of El Tamarindo is located at the head of tidewater about 5 km upstream from the mouth. Four esteros or tidal creeks, Estero Ciega, Rio Izapa, Estero la Cangirce, and Estero de las Coyundas, are tributary between the mouth and El Tamarindo. The effluents of the Tamarindo River are separated from Lake Managua by a narrow strip of land 20-30 m above the normal surface level of the lake.

Land use between Lake Managua and the Tamarindo power development site consists of agriculture on the lake flats and then primarily grazing onto the Pacific slope.

The village of El Tamarindo has a series of salt evaporation ponds which seem to be its primary source of support although it is also a source of labor for the port facilities at Puerto Somoza. An oil-fired powerplant is also located at Puerto Somoza.

Transportation in the area consists of two main north/south highways, Highway 28 near Lake Managua and Highway 12 near the Pacific. The railroad to Corinto has a spur to Puerto Somoza. Highway 32 branches off Highway 12 near El Tamarindo and proceeds to Puerto Somoza roughly paralleling the railroad.

The drainage area of Lake Nicaragua is approximately 23,333 km^2 including that of Lake Managua. The lake itself has a surface area of 8,133 km^2. The Tipitapa River, the link between Lakes Managua and Nicaragua, is intermittent in character and has carried flows between the lakes only twice in the past 50 years. It has a drainage area of 499 km^2. Along the eastern shore are many tributaries which have intermittent flow. In general, these rivers are used for irrigation of relatively small areas. The channels are less than 20 m wide and water depths are less than 1 m. The largest tributaries are the Tule River, the Tepenaguasapa River, the Oyate River, and the Mayales River. Deltas have been formed at the mouth of each river sometimes resulting in low swampy areas. Along the western shore near Managua and Granada, several small lakes occur which are not directly tributary to Lake Nicaragua. The normal lake level of Lake Nicaragua is 31 m above mean sea level. The record low is 30.73 m and the high is 33.3 m.

The water quality of Lake Nicaragua is high and it can be used for municipal, agricultural, and industrial purposes. Treatment for biological contamination would be required for municipal and some industrial purposes.

The shoreline of Lake Nicaragua is about 450 km long and has a highly variable vegetative cover. The coast from the Tipitapa River to Granada is low, sandy, and has an extensive swamp inland. Outside the swamp and in the vicinity of Panaloya, the vegetative cover consists of xerophytic forest and tropical savanna. Southeast of Granada and extending to Rivas, the shoreline is tropical savanna altered by grazing and agriculture. Beginning at the isthmus of Rivas the shore begins to become swampy and is the forerunner of the extensive swamps of the south shore. These swamps consist of a large cane grass, low bushes, and some open water areas usually covered or encroached by coarse grasses On old beach lines and along the natural levees of the numerous creeks, larger trees sometimes grow.

From San Carlos north on the Chontales coast to about the Oyate River, tropical rain forest has been replaced by growth and agriculture. The whole eastern coast as far as the Tipitapa River is a series of points and low deltaic areas for the numerous small rivers. It is essentially a low, marshy coast, which is used extensively for rice cultivation. All of the islands appear to be heavily vegetated with rain forest or second growth. The Solentiname Islands appear to be less covered than the others. Near shore and in the zone of fluctuation, the shoreline is usually sandy except where swamps prevail or in a few areas such as south of Granada where the coast is rocky and volcanic in origin, usually recent. The east side of the lake has some silt and clay shoreline in the deltas and associated areas of the small rivers.

Swamp areas consist of a large cane grass, coarse grasses, palms, and various water-dependent scrubby trees and bushes. Most swamps have various floating aquatic plants. The most common is the Water Hyacinth (Eichornia crassipes) or Liro de agua. In addition, Pistia stratiotes or Lechuga de agua, Salvinia sp., Anacharis sp., Azola mexicana, and duckweed (Lemna sp.) also occur. The floating aquatic plants also grow in mats along the riverbanks and on the portion of the lakeshores most protected from wind. Eichornia is usually the basic plant in the mat communities.

In Lake Nicaragua, the offshore winds on the east side of the lake often break off large masses of aquatic plants which find their way into the outlet and float down the San Juan River.

The Brito River on the Rivas Isthmus is a small river with a main channel length of about 24 km and tributary to the Pacific Ocean. The Lajas River is tributary to Lake Nicaragua and about 14 km long. The isthmus at the proposed construction site is about 24 km wide with a maximum elevation of less than 50 m.

Although the rivers have probably been sampled, no specific reports are available on the kinds of fish which occur in them.

Transportation in the area consists of the main north-south Highway 2 which parallels Lake Nicaragua and Highway 16 which connects Highway 2 with the coast.

The San Juan River leaves Lake Nicaragua at San Carlos and flows southeasterly about 205 km to enter the Caribbean Sea at two points, Barra del Colorado, Costa Rica, and San Juan del Norte, Nicaragua. Near El Castillo, Nicaragua, five major rapids occur over which the depth is 1 m in the dry season and over 2 m during high water. The channel is more than 80 m wide over its whole course. Starting about 5 km below El Castillo, the south bank of the river forms the international boundary. The high water period is from May through January with the peaks during June and October. The low water period is from February through April with the minimum flow occurring in either April or early May. The peak flow at the mouth is estimated to be 8700 m^3/s.

a. Fish and Wildlife

The fishes of the Tipitapa Project can be divided into several groups, i.e., Lake Managua species, species common to Lakes Nicaragua and

Managua, species of the San Juan River, the saltwater migrants common to Lake Nicaragua and San Juan River, and fishes of the Pacific slope found in the Tamarindo River drainage. There are about 45 resident freshwater and 6 migrant ocean species.

The commercial fishery in the great lakes is on about 20 freshwater species of the families Characidae, Pimelodidae, Lepisosteidae, Cichlidae, and, in Lake Nicaragua only, four or five saltwater migrants of the families Carcharinidae, Pristidae, Megalopidae Centropomiedae, and Pomadasyidae.

In terms of use, the guapote and mojarras (Cichlidae), gaspar (Lepisosteidae), and machaca (Characidae) are the most important. There are about 10 species on the mojarra group and two or three in the guapote group which are exploited. These all show a preference for shallow water (2-5 fathoms) or near shore weed beds as does the gaspar and machaca. The guapote, gaspar, and machaca are predators, and the mojarras include both predatory and plant-feeding types. The Characidae, except for the machaca, are small prey species. Several, such as Astyanax, are omnivorous and take virtually every kind of food of suitable size including small fish. The catfish (Pimelodidae) are bottom feeders and several species prefer the deeper waters of the lake (7-9 fathoms). The Poiciledae are small fishes, which are usually forage species and some of which play an important role in mosquito control. The sabalete (Dorosoma chavesi) is another deep water species (7-9 fathoms) and is an important forage species.

Data on the fish and fisheries of the San Juan drainage area including Lake Managua are still largely descriptive and ecological relationships are known for only a few species such as Cichlosoma citrinellum. Less information is available for the Tamarindo and Brito Rivers. The Lajas River probably has the same species as Lake Nicaragua.

About half of the bird species which occur in Nicaragua are in the broadest area of project influence. Three quarters of these are birds which will not be affected by the project. The balance, or about 90, are forest birds which may occur in the reservoir basin on the San Juan River although no comprehensive survey has been carried out.

b. Endangered Species

There is no list of endangered plants for Nicaragua. No endangered fish and wildlife will be affected by the Tipitapa Project. In the upper reaches of the Viejo River the howler monkey, jaguar, ocelot, margay, tiger cat, and mountain lion may be found but no project activity will occur in that area.

According to a brochure on hunting and fishing prepared by the Direccion Nacional de Turismo, protected animals in Nicaragua include mountain lion, jaguar, and otter through 1976, and manatee, tapir, wild pig, royal red coate mundi, and congo monkey (howler monkey) indefinitely. Protected birds include partridge, turkeys, mountain woodpecker (Guatemalan ivory bill), Guatemalan quetzal, house sparrows, herons, owls, and king vulture. Protected animals are not necessarily on the IUCN endangered list.

c. Recreation

Tourism is an important aspect of recreational income in Nicaragua. In 1974, 164,478 travelers were classified as tourists and in the first two quarters of 1975, 90,916 people were so classified. Between San Carlos and El Castillo near the confluence of the Sabalos River with the San Juan River, are located two tarpon fishing camps catering largely to North American tourists. The oldest of these, Tarpon Camp, has facilities for 16 people and prices for an individual range from $730 for 3 days to $980 for 8 days all inclusive from Managua. Approximately 100 people per season use this facility. There are several fishing hotels at Barra del Colorado, Costa Rica. These are neither large nor modern. Several hundred fishermen a year fly in and fish for snook and tarpon.

There are no organized hunting camps on the river or Lakes Nicaragua and Managua. Dove hunting principally on the north and east shores of Lake Nicaragua attracts local as well as foreign hunters seasonally. The marshes of Tisma are said to be good duck hunting areas and the eastern shore of Lake Nicaragua has similar hunting in the delta marshes of the several small rivers there. No records are kept of hunter numbers or take.

The beaches of Lake Nicaragua are attractive and heavily used in the vicinity of Granada. There is an extensive development of beach houses or quintas also near Granada. A similar development on Lake Managua exists on the Chiltepe peninsula.

One of the most attractive tourist areas on Lake Nicaragua are the Isletas of Granada. A number of small islands varying in size from a few square feet to several acres thickly covered with tropical vegetation. Boat tours are popular through them and most have recreational home developments. Some sport fishing for Mojarra and Guapote is done in the Isletas.

The beaches south of Puerto Somoza are used extensively by recreationists and there is a beach home development in that area. Likewise, the beaches associated with the Brito River are well used recreation areas.

d. Historic and Archeological Sites

A preliminary archeological survey has been made of a portion of the San Juan River. Surface indications have consisted of pot shards at a number of locations principally near the confluence of the larger tributaries with the San Juan River. These have not been dated beyond the indication that they may be pre-Columbian. No comprehensive archeological survey associated with the project has been made on Lake Managua or Nicaragua, although sites are known to occur extensively on both lakes. No survey has been made along either the Tamarindo canal route or the alternate Rivas-Brito route.

3. Environmental Effects

a. Project Summary

A dam on the San Juan River is common to the Tipitapa as well as the Rivas Isthmus alternative. One of two alternative damsites on the San

Juan River will be selected which will create a stabilized Lake Nicaragua surface and sufficient storage to provide a 500-m^2/s diversion.

The San Isidro damsite is located just below the Sabalos River approximately 42 km from San Carlos. The alternate Chorrera damsite is a further 38 km downstream just below Cano la Chorrera.

The Tipitapa alternative consists of a dredged intake canal about 17 km long which takes off from the northern part of Lake Nicaragua near the Tipitapa River mouth and ends at a pumping station and dam on the Tipitapa River about 9 km from the village of Tipitapa (Pasquier damsite). The dam would have a crest length of about 300 m and a crest elevation of 41 m. A canal would be excavated from Lake Managua to the Pasquier damsite which would have a capacity of 600 m^3/s.

Water pumped from Lake Nicaragua into Lake Managua would be diverted by a canal into the Pacific Ocean drainage (Ceiba Mocha Cut) where it would be used for hydroelectric production at a powerplant near El Tamarindo. The Lake Managua/Tamarindo Canal would have a capacity of 500 m^3/s. The canal would depart Lake Managua at a point about halfway between La Paz Centro and Nagarote. Two alternatives for the powerplant are proposed. One is a power canal about 19 km long which would deliver the water directly to the powerplant directly through a penstock system. The other consists of a 7-km canal, a dam on the Tamarindo River with a crest length of 2000 m, a crest height of 40 m, and a reservoir surface area of 40 km^2. The powerplant would be situated at or near the foot of the dam. A dike along the west side of the Tamarindo River watershed is a part of the reservoir plan and would be about 6000 m long.

For the first alternative the continuous discharge would amount to 500 m^3/s generating 144 MW. The second alternative would have a discharge ranging from 200 m^3/s to 800 m^3/s averaging 500 m^3/s. The total plant capacity would be 234.4 MW.

The Rivas Isthmus alternative is located on the isthmus about 8 km south of Rivas. The water supply takeoff from Lake Nicaragua is located at the mouth of the Lajas River near La Calabria. The works would consist of a canal utilizing the channel of the Lajas River for about 2.5 km, channel improvement on the Guiscoyal River for about 1.5 km, and a rock cut section of about 9.6 km which would terminate in a reservoir on the Brito River which is tributary to the Pacific. The Brito Reservoir would have a surface area of about 28.5 km^2, an operating height of about 30.3 m, and a maximum control level of about 33 m elevation above sea level. The powerhouse would be located downstream and discharge to the Pacific Ocean through a canal and jetty system. The diversion from Lake Nicaragua would be about 500 m^3/s and generate 114 MW of power.

An alternate, the Miramar Dam and Reservoir, also on the Rio Brito, would generate approximately the same amount of power with the same diversion. This reservoir would be located higher on the river, about 6 km from the Pacific Ocean. It would have a surface area of about 14.7 km^2. A power canal would transport the water to a powerplant near the ocean.

b. Construction

Construction impacts will have relatively short-term effects.

The placement of the cofferdams in the San Juan River to permit the excavation for the damsite and construction of either of the alternative dams will temporarily increase turbidity downstream. The same will hold true when the river is diverted into the newly cut channel and again when the cofferdams are removed and the river diverted back into its original channel. Fish may be disturbed by the temporary increases in turbidity, although it is unlikely the increase will be much above normal flood season levels.

Dredging in Lakes Nicaragua and Managua for the canal intakes will cause turbidity temporarily.

Compared to the present ambient air and noise quality, the change during construction will be substantial. Earthmoving equipment and stationary sources such as generators, as well as virtually all other activities, will contribute hydrocarbons and noise. Dust will probably be a problem during the excavation of the canals and dam construction at either the Tamarindo or the Rivas Isthmus alternatives. It is less likely to be significant at the Tipitapa River sites and not at all either alternative site on the San Juan River.

There is a high potential for erosion at the San Juan River sites since the rainfall is high and often intense. On the San Juan River, vegetation covers disturbed areas in several areas, equipment activity will probably interface with this natural protective process and delay it until construction activity is completed. In other potential construction areas, erosion problems may be a problem but easier to control due to the lower rainfall.

Construction specifications should include provisions to minimize water, noise, and air pollution, as well as safety hazards. Erosion control throughout all the construction areas particularly for excavations, stockpiles, and haul roads is important but especially so in the high rainfall zone and should be planned for in the other zones.

Powerlines would have to be constructed to deliver power to load centers. From the Rivas Isthmus alternative to Managua this would entail a powerline about 100 km long. From the Tamarindo alternative it would be about 50 km although an additional line would need to be brought into the pumping plant on the Tipitapa River. In each instance power could conceivably be sent to other locations than Managua. Powerlines require right-of-way which can interfere with other land uses, esthetics, and large birds. A survey of the route should include archeological and historic aspects.

c. Hydrology

The greatest impact on San Juan River hydrology, depending on the damsite selected, would be the conversion of about 42 to 80 km of free-flowing stream to a reservoir. The flow of the San Juan River below either of the alternate damsites would be affected by the diversion of approximately 500 m^3/s through either the Tamarindo or Brito River alternatives. Operations studies have not been completed so analysis of fluctuation effects, pumping, or the storage of floodflows on Lake Nicaragua cannot be assessed.

The natural fluctuation of Lake Nicaragua ranges from 31 to 33.3 m above sea level. The high level control at both the San Isidro and Chorrera Dams is 34 m with the top of the dam at 36 m. The normal operating height of the water surface at the dam will be 31 m. Any level above this to 34 m will be the result of floodflows. Whether or not the higher levels would affect Lake Nicaragua depends upon such things as where the floodflows originated, the amount and timing of rainfall in various portions of the drainage, the conformation of the reservoir, etc., all conditions which would be examined by an operations study.

The effect of floodflows on Lake Nicaragua being held behind San Isidro Dam would be more noticeable due to its nearness to the lake since there would be less opportunity for dampening the bounce by dispersion in the flooded area.

If the 34-m level at the dam was to be transferred temporarily to Lake Nicaragua, the efect would be a 0.7 m rise over the historic high level for a short period of time. This would affect some near-shore installations, but there would be little or no measurable effects during the short period of inundation on fish and wildlife and vegetation. There would be a 3 percent increase in surface area mostly affecting the swamps on the south shore, some of the low deltaic areas on the east shore, and in the Tisma lagoon and swamp area along the Tipitapa River.

With the Tamarindo River alternative there will be a marked change in the hydrology of the Lake Managua drainage in that it will no longer be tributary to the San Juan River system and the Atlantic Ocean but will be a part of the Tamarindo drainage into the Pacific Ocean.

The Rivas Isthmus alternative will place Lake Nicaragua and the Lake Managua drainage in both the Pacific and Atlantic Ocean drainages with Lake Managua remaining tributary to Lake Nicaragua via the unchanged Tipitapa River.

The environmental impacts of this alternative on Lake Nicaragua and the San Juan River will be the same as for the Tamarindo alternative.

d. Water Quality

The reservoirs on the San Juan River will function as a sediment trap for the material being brought down from the Costa Rican volcanoes by the Frio River. The flooding of new land and vegetation will increase the available nutrients in the river initially. After a few years, these influences will be modified by leaching and decay and the nutrient level will become whatever the flooded soil potential and the character of the inflow from tributaries and Lake Nicaragua are.

The effects on the San Juan River estuary will result from decreases in turbidity and sediment load, nutrient entrapment, and possibly some smoothing of flood peaks. The significance of the reduction in the amount of annual flow which would occur due to the diversion of 500 m^3/s is not known and could be evaluated by an operations study.

The removal of the sediment being carried into the San Juan River principally by the Frio River will increase scouring downstream from the dams, deepening the river but shallowing the rapids and possibly affecting sediment deposition in the bay and along the coast in the direction of the shore transport. This could have a beneficial effect on river transport between Chorrera Dam and the San Carlos River, a heavy contributor to the silt load in the San Juan River. The shallowing of the rapids below San Isidro Dam would be detrimental to river transportation. The long-term effect cannot be assessed at this time.

The impacts associated with sediment and nutrient entrapment are tentative and can be more fully described when the operations study is completed.

The movement of 500 m^3/s from Lake Nicaragua into Lake Managua and the simultaneous transfer of a like amount out of Lake Managua into the Tamarindo River drainage will have a profound effect on Lake Managua. In approximately 1 year the water quality of Lake Managua would be the same as that of Lake Nicaragua except for differences caused by inflow into Lake Managua from mineral springs and tributaries.

The Tamarindo River outlet into the Pacific will have an average flow of about 500 m^3/s of fresh water during powerplant operation. This will have considerable effect on the ecology of what is now a salt and brackish water estuary with a highly variable amount of annual fresh water flow.

The same effect will be had on water quality in the estuary of the Brito River in the Rivas Isthmus alternative.

In both estuarine instances an operations study will be necessary before a good estimate of water quality effects can be made.

e. Public Health

In place of a free-flowing river, there will be a reservoir of standing water at elevation 31 m with a potential high water elevation of 34 m. Although the potential fluctuation of 3 m is unlikely to occur, some annual or seasonal fluctuation may be present. This would mean periodic creation of shallow standing water pools, which would be conducive to the production of certain mosquitos. Conversely, however, the shoreline fluctuation can be manipulated to curtail production of other kinds of mosquitos. Snail production will be enhanced by standing water. Much of the shoreline will be highly convoluted and shallow. Both conditions favoring mosquito and snail production.

The spillway at either dam on the San Juan River will be in continuous operation and would be excellent habitat for blackfly (Simulium) production, since it will consist of swiftly moving water over a smooth surface, not unlike a waterfall or shallow rocky rapids, both of which are good habitats for this insect.

If standing vegetation is not removed, the increased "edge" of the flooded plants and the stilling effect of the flooded trees on wave action will be conducive to mosquito production.

The workforce on the project could be drawn from all over Central America as well as other areas because of the wide variety of skills which will be required. Some of these people will be infected with various parasites such as malaria, yellow fever, shistosomiasis, onchorcerciasis, and various intestinal parasites. The vectors for all of these parasitic diseases are now present in the San Juan River area, although, except for malaria carrying mosquitos, usually not infected. The introduction of a workforce and the attendant families, support services, and camp followers has a tremendous potential for sanitation-related problems. This will be particularly so on the San Juan River portions of the project.

Another problem, which is perhaps more of a safety nature, is that concerned with poisonous snakes. They are numerous in numbers and kinds in the area of construction and in the areas to be flooded. The greatest danger in the construction area will be during the earliest stages when extensive clearing is done. Most of the snakes will abandon the area due to excessive activity but constant vigilance will be necessary. A second period of danger will occur on the San Juan River during early flooding when the reptiles will be concentrated on high ground or floating debris. The best precaution is an education program and a trained hospital staff with the various kinds of antivenom on hand.

A program of screening all workers for infections and vector-borne diseases should be routinely carried out. Positive cases should be treated or denied employment until cured. A regular program of preventive medicine should be instituted as a project expense.

Environmental hygiene should be an important aspect of the project including provision and monitoring of a safe water supply, sewerage system, housing, food service, and solid waste disposal.

Insect and rodent control will also be important at the construction sites, including water control in swamps and ponds by efficient drainage systems, chemical control of insects and rodents, preventive construction measures such as screening of habitations and offices, vegetation control, and solid waste control.

Engineering solutions should be sought for vector control in the reservoirs which will be created. This would consist of actions such as the provision of means for quick drainage of low swamp areas and ponds which would become isolated during water level fluctuations.

The shoreline of the reservoirs should be cleared so that the shallows would have no emergent vegetation. This, in combination with fluctuations, can be an effective mosquito control effort.

A public health study should be carried out in the next phase of the design and study for the project. It should be done when operations as well as engineering data are more complete.

Neither the Tamarindo nor the Rivas Isthmus alternative, other than creating the large standing water areas of the reservoirs with the attendant potential for mosquito production, has any known adverse public health aspects. Should there be an opportunity to use some of the powerplant discharge for water intensive cultivation such as rice, a water-borne vector problem might occur.

f. Plant Communities

The natural plant communities on the San Juan River above San Isidro damsite have been drastically modified by agricultural development. Most of the readily available high value timber has been cut over near the river for valuable woods such as mahogany and rosewood, but a large area of rain forest remains in the Sabalos River drainage where logging is continuing.

The Chorrera damsite, being about 38 km further downstream than the San Isidro site, will flood additional forest lands similar in kind and condition to the upstream areas. For either damsite the most valuable woods are in Nicaragua as settlement and clearing for farming and stock raising is more advanced in Costa Rica although the largest cleared stock ranch is in Nicaragua upstream from the Sabalos River. Extensive cattle ranching was also noted on the Frio River.

g. Fish and Wildlife

There are about 45 resident freshwater fish species in the great lakes and the San Juan River and an additional 6 saltwater species which seasonally migrate into the freshwater of Lake Nicaragua.

Ecologically, the effect of either the San Isidro or Chorrera Dam on the saltwater migrants will be to exclude them from the upstream areas. The shark will persist in Lake Nicaragua for perhaps several years but since it has apparently never fully adapted to freshwater in the breeding cycle, it will eventually disappear. The two species of sawfish, one very rare in freshwater, may persist since they are known to breed and give birth in Lake Nicaragua. There is some indication that during their juvenile period, however, sawfish may need to return to estuarine or saltwater. If this is so, then they too will become extinct in the area above the dam after a few years. The other three saltwater species, snook, grunt, and tarpon, will all disappear in the area upstream from the barrier. In addition to their value as food, these fish, particularly the shark, are a matter of some pride to Nicaragua. In the instance of the shark, its importance to the people of Nicaragua as something unique to their country may outweigh any economic or ecological considerations.

The effect of the project on the movement of saltwater fish into the San Juan River estuary and upstream to the face of the dam cannot be clearly assessed. The project would be essentially a pass-through operation, except for the diversion of 500 m^3/s and since the principal tributaries of the San Juan River are downstream from the dams, the attractive force of the flow would remain and a concentration of migrating a fish can be expected to appear in front of either of the dam alternatives. The flow below the dam will probably be less turbid due to the entrapment of Frio River contributed sediment until the San Carlos River enters the system downstream.

It is not known whether or not the migratory marine fishes of the San Juan River-Lake Nicaragua system will move upstream through a ship lock. Apparently sharks have not moved into Gatun Lake, Canal Zone, through the ship locks of the Panama Canal, although the same species of bull shark is found in the Caribbean there. There is also no information on whether any of the marine migrants in the San Juan River will move through a fishway. The feasibility of modifying a locking system to accommodate fish passage or, in its absence, the provision of a fishway should be investigated from a biological and engineering standpoint.

With the data now at hand, it appears that the freshwater fish in the lake will not be affected by impoundment, although detailed effects cannot be assessed without more ecological data. For instance, what would be the effect of removing the large saltwater predators on the freshwater populations in the lake?

The present level of commercial fishing on the resident freshwater species in Lake Nicaragua is low. With the removal of the shark and potential removal of the sawfish, both important commercial fishes, it is possible the demand for fish to fill this loss could increase commercial fishing pressure on the freshwater residents and at least partially replace the removed predator pressure.

Some of the questions regarding the effect of removing the large marine predators from Lake Nicaragua and the upper San Juan River could be resolved if more data were available on ecological requirements and relationships of the resident fish populations. There are experts in both Costa Rica and Nicaragua who could carry out such studies.

An effect on riverine freshwater species upstream from the dam will be the substitution of a lacustrine habitat for the present fluvial one. Fishes such as the guapote and mojarras, which now occur in lesser numbers in the river than in the lake, will increase in the reservoir. Some essentially riverine species will decrease but none will become extinct since tributary rivers will remain. As in the instance of the lake fishes, the effect of impoundment can be assessed only when additional ecological data are available. The initial flooding of the reservoir basin will flood new fertile land and much vegetation. The nutrients can be expected to leach out of these into the impounded water. They can be utilized in place by aquatic plants and animals and also be flushed downstream. There is the likelihood that nutrients downstream will increase initially with impoundment but over the long term, when utilization is balanced by replacement in the reservoir, the impoundment can be expected to function as a nutrient trap.

In the instance of juvenile shrimp and fishes in the estuary, the expected change in turbidity or nutrients will probably have little effect.

Effects on wildlife are less easily understood because of the lack of information on the kinds of wildlife, which occur in the areas to be influenced by the dam and reservoir. The most obvious effect on wildlife, however, will be the flooding of about 29 500 ha of terrestrial habitat by the San Isidro Dam alternative or 31 700 ha by the Chorrera Dam alternative. The effect is not only due to the loss of habitat or the drowning of wildlife but also to the movement of animals and birds fleeing the rising water into habitats now occupied by similar animals and birds.

The Tipitapa/Tamarindo alternative will, in addition to the effects just described, markedly change the fish fauna in Lake Managua and the Tamarindo River. Even though only one species has apparently been described in Lake Managua which is specific to that water, the differences in water quality and the tributary streams may have uniquely adapted other fishes in the lake. Fishes and other aquatic life adjusted to that regimen may not adjust to the rapid change in water quality, i.e., 1 year for a complete flush, and be lost. Lake Nicaragua fish not now found in Lake Managua will be pumped in and complete with native fishes. As in the instance of Lake Nicaragua and the San Juan River, the impacts cannot be adequately assessed without a fisheries study emphasizing ecological and behavioral relationships in Lake Managua and the Tamarindo River.

Wildlife effects of this alternative will be primarily associated with the conversion of terrestrial to aquatic habitat.

The intake canal from Lake Nicaragua to the Pasquier damsite where the pumping station will be located has a potential for lowering the water in the Tisma lagoon and swamp, an important waterfowl area.

Brito Reservoir will flood about 28 km^2 and its alternate Miramar Reservoir about 15 km^2. As with the Tipitapa/Tamarindo alternative, wildlife effects will consist of the conversion of these areas from terrestrial to aquatic habitat. No wildlife surveys have been made so the numbers and kinds of animals to be displaced are not known. Fishes will be transferred into the Brito River drainage from Lake Nicaragua and the San Juan River. The Brito River is in the same fishing province as the Tamarindo River although no data are available as to what fish species actually do occur there. No endangered fish or wildlife are known in the area.

The next planning phase for this alternative should include a fisheries survey of the river to be affected.

The addition of a stream of about 500 m^3/s of freshwater into the estuarine area of the Brito River will have considerable effect on the estuarine and marine fauna. No study has been carried out which describes what plants and animals are now there or their importance.

The next planning phase should include a biological survey of the estuarine and marine resources.

The Rivas Isthmus alternative will preclude the necessity of a diversion into the Lake Managua/Tamarindo River drainages and the benefit of freshening Lake Managua would be foregone.

During the first years of pumping from Lake Nicaragua into Lake Managua and the diversion into the Tamarindo River drainage or the movement of water into the Brito River drainage from Lake Nicaragua there is the possibility of transferring some of the Atlantic derived marine fishes into the Pacific Ocean. After either the San Ysidro Dam or Chorrera Dam alternative is in place on the San Juan River these fish, in the absence of a fishway, will be excluded from Lake Nicaragua. It will take some years before they are actually absent from the lake. The sawfish may be able to continue in the lake but at a lower level. Insofar as is known at this time none of the marine species migrating up the San Juan River into Lake Nicaragua are found in the Pacific Ocean. The Rivas Isthmus alternative has the greater potential for transfer of these fishes into the Pacific due to its nearness to their entrance into Lake Nicaragua and also because no pumping will be necessary to move the water into the Brito River watershed. This possibility has been of international concern with the sea level Panama Canal proposal and should be carefully considered here.

h. Recreation

The creation of the dam, reservoir construction village, and airstrip on the San Juan River will create a tourist attraction. The airstrip will be macadamized and, if maintained, will be an attractive force for visitors. The same applies to the village, which will have reliable water, sanitary facilities, and housing superior to anything now in that part of Nicaragua.

The reservoir will also offer the opportunity of easier boat trips down the San Juan River to either damsite. Deeper water would permit the use of larger, more comfortable vessels.

Resthouse-type accommodations will be provided for short-term visits of experts and officials to either damsite during construction. While some need for these facilities will continue after the project is completed, a portion could be reserved to provide tourist accommodations.

Tarpon and snook fishing at the two camps near the Sabalos River would be eliminated. The estuarine fisheries for these species should be unaffected.

There is the potential for a concentration of marine fish such as tarpon, snook, grunt, and swawfish below either dam on the San Juan

River. The shallowing of the rapids at El Castillo by the San Isidro Dam could interfere with upstream passage of these fish but no sucn potential obstacle would exist below Chorrera Dam.

It is true that upstream water developments have been credited with adversely affecting estuarine and riverine tarpon fisheries elsewhere, but these are instances where water has been stored and a significant part of the natural flow diverted. There is the potential mitigative measure of government assistance for the reestablishment of the sport fishing camps at either of the San Juan River damsites if the concentrations of marine migrants suggested above occur. The operations study which has been maintained elsewhere would evaluate the effect of the 500-m^3/s diversion upon the regular flow of the San Juan River. This would give a better indication of the amount of the downstream flow which would continue to function as an attractant to the marine migrants.

i. Navigation

The river community as a whole is now dependent upon a subsistence economy with little cash inflow. The opening of easier access to markets will tend to alleviate this condition.

Development on the river is stalled because of the distance from markets and the difficulty of transport. Easier access up the river would cause an expansion of agricultural production and marketing opportunities.

Taking the assumption that a navigation element will be included in either of the dams on the San Juan River, any improvement in river transport will benefit the economy and well-being of the San Juan River

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population in both Nicaragua and Costa Rica. Families now forced to rely on expensive and arduous transport of products to markets will have relatively easy transport in quiet, deep water above the dam. Even the use of sail-powered craft would be possible.

The Chorrera Dam alternative would probably be most effective since the river would be deepened for over 70 km in the area where the rapids occur. The San Isidro Dam would probably shallow the rapids at El Castillo making special locking arrangements or overland transport facilities necessary.

j. Historic and Archaeological Elements

The principal historic site on the San Juan River, the fort at El Castillo, would not be affected although portions of the El Castillo community would be flooded by the Chorrera Dam alternative. The rapids at El Castillo which figured in the historic action against the British invaders would be covered by the Chorrera Dam alternative and shallowed by the San Isidro Dam.

Flooding, however, will cover potential archaic Indian sites between either alternative dam and Lake Nicaragua. Canal and appurtenant works construction has the potential for the destruction of other sites. The reservoir alternatives for both the Tamarindo and Rivas Isthmus alternatives also may cover archaeological sites.

A reconnaissance survey should be made for aboriginal Indian sites and test pitting carried out at identified sites. Should the sites prove significant, salvage excavations should be undertaken.

Table 1. - Estimates of areas to be inundated by dams on the San Juan River

San Isidro Dam

	Costa Rica Medio Queso River Frio River	Nicaragua San Juan River	Total
	(hectares)		
Cropland	2 000	2 100	4 100
Pasture	1 600	12 200	13 800
Brush	330	--	330
Forest	2 600	6 700	9 300
Swamp	--	2 000	2 000
Total	6 530	23 000	29 530

Chorrera Dam

	Costa Rica Medio Queso, Frio, Poco Sol and Infernito Rivers	Nicaragua San Juan and Santa Cruz Rivers	Total
	(hectares)		
Cropland	3 000	2 390	5 390
Pasture	2 315	12 715	15 030
Brush	485	--	485
Forest	3 795	6 990	10 785
Swamp	--	2 020	2 020
Total	9 595	24 115	33 710

4. Socioeconomic Effects

The addition of about 114 to 144 MW of power to the economy of Nicaragua will have powerful socioeconomic consequences beyond the scope of this study to fully evaluate.

Communities now dependent upon diesel units for power generation could rely largely on a hydroelectric source and use diesel or other hydrocarbon-fueled sources as emergency or standby power. Estimates of savings in terms of barrels of oil per year to replace the same amount of power, which would be provided by the project in the 114-144 MW range, would be about $833,000 to $1,000,000 at a 1975 cost of about 10 to 13 million dollars (U.S.A.). These estimates are based on a powerplant which operates continuously.

a. Industry

The new source of electrical energy will stimulate continued industrialization providing more job opportunities and lessening dependence on imports. These are secondary impacts, the quantification of which must await extensive economic analysis. More industry also has the potential for creating air quality, water quality, and noise degradation in addition to social ills, which are associated with the urbanization which usually accompanies industrialization.

The Plynica plywood plant on the Tipitapa River about 9 km downstream from the village of Tipitapa would be adversely affected by increased costs of log transport up the San Juan River unless a locking system or some other way of moving logs around the San Juan River dam was provided. In addition, any alternate site for the Tipitapa River dam and pumping plant other than the Pasquier damsite about 9 km below Lake Managua would flood the Plynica plywood plant. Even with the plant being unaffected by flooding, increased velocities in the Tipitapa channel caused by pumping into Lake Managua may preclude the further use of the river for log transport.

Less power will be generated by the Rivas Isthmus alternative and a greater transmission loss can be expected. There will be an unknown effect on the rate and kind of industrial development which could occur in the country due to this difference and there will probably be a smaller savings in other fuels used for power generation.

The Rivas Isthmus alternative will not impact the Plynica plant although the barrier effect on moving logs above either damsite on the San Juan River will remain.

b. Urban

The community of San Carlos may have some of its shoreline installations flooded at times of high waters. An operations study will indicate whether or not this will occur.

Secondary impacts on urban areas could be the improvement of life-styles due to reliable and clean hydroelectric power, a better job market and standard of living as a result of increased opportunities in industry.

The San Isidro Dam alternative would flood out the small settlement at the mouth of the Sabalos River. This settlement could be located further up the Sabalos River since it now functions as a shipping point for logs being brought down that river for shipment up the San Juan River. This dam would not affect the El Castillo community except that the shallowing of the El Castillo rapids by the upstream diversion of about 500 m^3/s would necessitate some other means than barge traffic to move cargo past this point on the San Juan River. El Castillo could be the terminus of rail or road transport to a shipping point behind the dam, in which case its economic status would remain the same or be improved.

The Chorrera dam alternative would flood about 30 buildings at El Castillo. The El Castillo rapids would be covered making them readily navigable and the need for the community of El Castillo as a river port doubtful.

c. Public Health

Given the implementation of the suggestions for public health actions made in section 3, Environmental Effects of the Project, the social effect in this area could be salutory. The influence could pass well beyond the immediate project area. Examples abound with one of the best known being the Tennessee Valley Project in the United States.

Only the most rudimentary knowledge of sanitation and disease control exists in the rural areas. The example of a well-run construction camp with safe potable water, sanitation, and health care alone should be helpful.

Workers experiencing camp facilities will take the knowledge of what can be done back to their communities when the project is over.

d. Agriculture

On the San Juan River about 4100 ha of agricultural land will be flooded by the San Isidro Dam alternative and 5390 ha by the Chorrera Dam alternative in Nicaragua. Pasture lands to be inundated amount to about 1600 ha in Costa Rica and 12 200 ha in Nicaragua for the San Isidro Dam alternative and about 2315 ha in Costa Rica and 12 715 ha in Nicaragua for the Chorrera Dam alternative. In each instance the people involved will have to be relocated, most probably on lands not now in use for these purposes. This means that from about 17 900 ha of forest or otherwise uninhabited land will be developed to replace the inundated crop and pasture land.

The value of the agriculture products now being produced on the lands to be flooded is not known since they are part of a larger reporting unit. Neither can the loss to be expected during the transition from the old to the new producing units be calculated at this time.

Plans for resettlement and compensation should be completed early in the planning. In addition to the usual compensation for loss of land and appurtenant facilities, provisions should be made for movement to new lands, the preparation of the new land, and an extension service to advise and assist in the use of the new land so as to assure the best long-term uses and practices are applied. A long-term development and operation loan program could be initiated for the displaced agriculturalists.

e. Forestry

The loss of timber land is estimated to be about 2600 ha in Nicaragua for the San Isidro Dam alternative and 3795 ha and 6990 ha, respectively, in the two countries for the Chorrera Dam alternative. These are all cutover lands from which the most valuable timber has already been removed. The most valuable timber land is in Nicaragua. This is a first-time loss and does not consider the long-term losses associated with a renewable resource.

Mitigative measures would take the form of compensation and advance planning to minimize or avoid the consequences of a glut or an ill-planned and wasteful timber salvage operation.

f. Fisheries

The construction of either of the dams on the San Juan River will have little, if any, adverse direct effect on the freshwater fishes of the San Juan River drainage including Lake Nicaragua. The migrant saltwater species will be barred from water upstream from the dam unless a fishway is provided.

At the present time (1976), there is at least one fishing company operating out of Granada, which is exploiting sawfish and shark, although two have been reported (Thorson, 1976). One company has a plant capacity of 909 kg/day for freezing and a cold storage capacity of 13 636 kg. Two transport boats, which have a combined cold storage capacity of 8,409 kg, are employed to pick up catches. About 50 fishermen in San Carlos are supplied with gear and their catches bought at the rate of C$0.75 to C$1.10 per kg. In June 1976, no fishermen were operating out of San Carlos and there were indications the fishery is seasonal and reaches its height there when the sharks and sawfish are moving into the lake in largest numbers, i.e., summer and fall. Fishing, however, occurs throughout the lake in all seasons, albeit at a sometimes desultory level.

The shark fishery would be eliminated. Without the connection to the sea, the sawfish fishery would continue its decline and eventually become unprofitable. There is some indication sawfish can maintain a population without the sea connection. The pattern of recent fishing moving to the area near San Carlos and its apparent seasonality, however, indicates much of the sawfish yield in Lake Nicaragua comes from new migrants.

The removal of the annual yield of about 230,000 kg of processed sawfish meat from Lake Nicaragua will be a significant impact in terms of food and income. There is the possibility that this impact is already happening and would occur from overfishing regardless of the dam or a fishway.

There is a small commercial shark fishery in the estuary at Barra del Colorado, Costa Rica, which should not be affected unless the change in flow characteristics below the dam affect the estuarine habitat of the shark in some unforeseen manner.

Roncador (grunt), robalo (snook), and sabalo real (tarpon) are also taken from the lake and river system. No data are available on amounts. The first two species are taken by commercial as well as sport fishermen, the latter by sport fishermen. Sabalo real is the prime target of two sport fishing camps on the San Juan River near the Sabalos River. Fisheries for all three of these species would be eliminated without a fish passage around the dam.

The feasibility of passage above the dam by the marine migrant fish should be investigated. Either a fishway or a modification of ship lock operation may be possible. Both considerations should be studied by a team of hydraulic engineers and fishery specialists with experience in design and operation of fish passage facilities.

In other instances where fisheries have been lost, fishermen have been retrained (Africa), compensated (U.S.A., Canada), or reoutfitted with the gear necessary to pursue other species of fish (Africa). There is a freshwater fishery resource in Lake Nicaragua which is not fully exploited to which the sawfish fishermen could turn, the exploitation of which would require different kinds of nets, boats, and processing facilities. A mitigative obligation may be present which could be handled by retraining and some reoutfitting of gear and processing facilities. Some marketing and development studies may also be appropriate.

5. Summary of Mitigative Recommendations

a. Construction specifications should include water, air and noise pollution, and erosion control measures.

b. Air operations study, which includes the effects of floods, droughts, and operations on reservoir levels, Lake Nicaragua levels, and downstream flows during operation and flooding, should be completed.

c. A public health study to further diagnose problems in the project area, which might affect construction, operations, and the residents, should be carried out. Interim measures could consist of:

(1) Screening all workers for infections of water-borne vector diseases such as malaria, filariasis, onchocerciasis, and shistosomiasis
(2) Instituting environmental hygiene controls on waste disposal, insect and rodent control, and potable water supplies
(3) The consideration of engineering solutions to vector control such as quick drains for standing water during fluctuation and clearing shoreline and vegetation which would be emergent during normal operations periods
(4) The development of operations solutions to vector control such as fluctuation to inhibit mosquito productions

d. The feasibility of providing a fishway over the dam on the San Juan River or modifying a ship lock for fish passage should be studied by an engineer/biological team with experience in fishway needs and designs. The system under consideration should be able to pass the migrant marine fish including sharks and sawfish.

e. Data now available on fish population are largely descriptive. More information is needed on ecological requirements and relationships. An example of a question now raised, which cannot be answered, is concerned with the effect of removing the large saltwater predators, i.e., the shark and sawfish, on the resident populations of fish in Lake Nicaragua. Estuarine impacts could also be more realistically evaluated.

f. Only the most general knowledge of wildlife in the area to be inundated is now at hand A wildlife survey is needed, which will determine the kinds, distribution, and numbers of wildlife including birds in the area to be impacted by inundation. This would include a further determination of threatened and endangered wildlife. This survey would also include an evaluation of islands, which will be created by inundations as possible areas for wildlife, which could be set aside as permanent refuges. The need for possible rescue operations would also be determined by the survey.

g. There is the possibility that the loss of the tarpon sport fishing camps near the Sabalos River could be compensated for by their reestablishment below the San Isidro Dam if tarpon, snook, shark, and other migratory marine fish concentrate below the dams. Government or project financial assistance and agreements would be required.

h. A reconnaissance archaeological survey should be made of the area to be inundated or affected by construction. First priority should be given to the construction zone. Salvage operations should be carried out where the reconnaissance survey indicates important archaeological values are located.

i. Socioeconomic Considerations

(1) The secondary impacts of the effect 114-144 MW will have on the rate of industrialization and its concomitant effects such as air, noise and water pollution, and population could be determined. This would be valuable data basic to planning for an orderly and productive expansion of the economy.

(2) Planning for the movement of El Castillo to a location above the influence of the reservoir if the Chorrera damsite is chosen as well as the smaller communities such as Boca Sabalos, should proceed with the design and construction schedule so as to reduce relocation hardships. Services such as potable water supplies, sewage disposal, schools, and church should be included.

(3) Planning for relocation of agriculturists should be completed early in the project so as to minimize economica and social impacts. Plans should include provision for transport, reconstruction, communications, and community services. Consideration should be given to establishing a long-term loan program to assist farmers and ranchers in reestablishing their enterprises.

(4) New lands will be opened or developed to relocate agriculturists. This will result in a whole series of secondary environmental impacts which should be considered and mitigated for in the early planning procedures.

(5) Forest salvage operations should be planned early in the project so as to avoid such impacts as an economic and processing glut, loss from storage, or loss from inundation of valuable timber.

(6) If the fishway or modified ship lock concept is not feasible, then the shark and sawfish fishery on Lake Nicaragua will disappear, resulting in a loss of employment, and fish protein. A program of retraining and reoutfitting fishermen to exploit the other potential lake fisheries such as guapote and mojarra could be undertaken. The present processing industry should also be reviewed since some financial aid may be necessary for it to turn to handling the other kinds of fish.